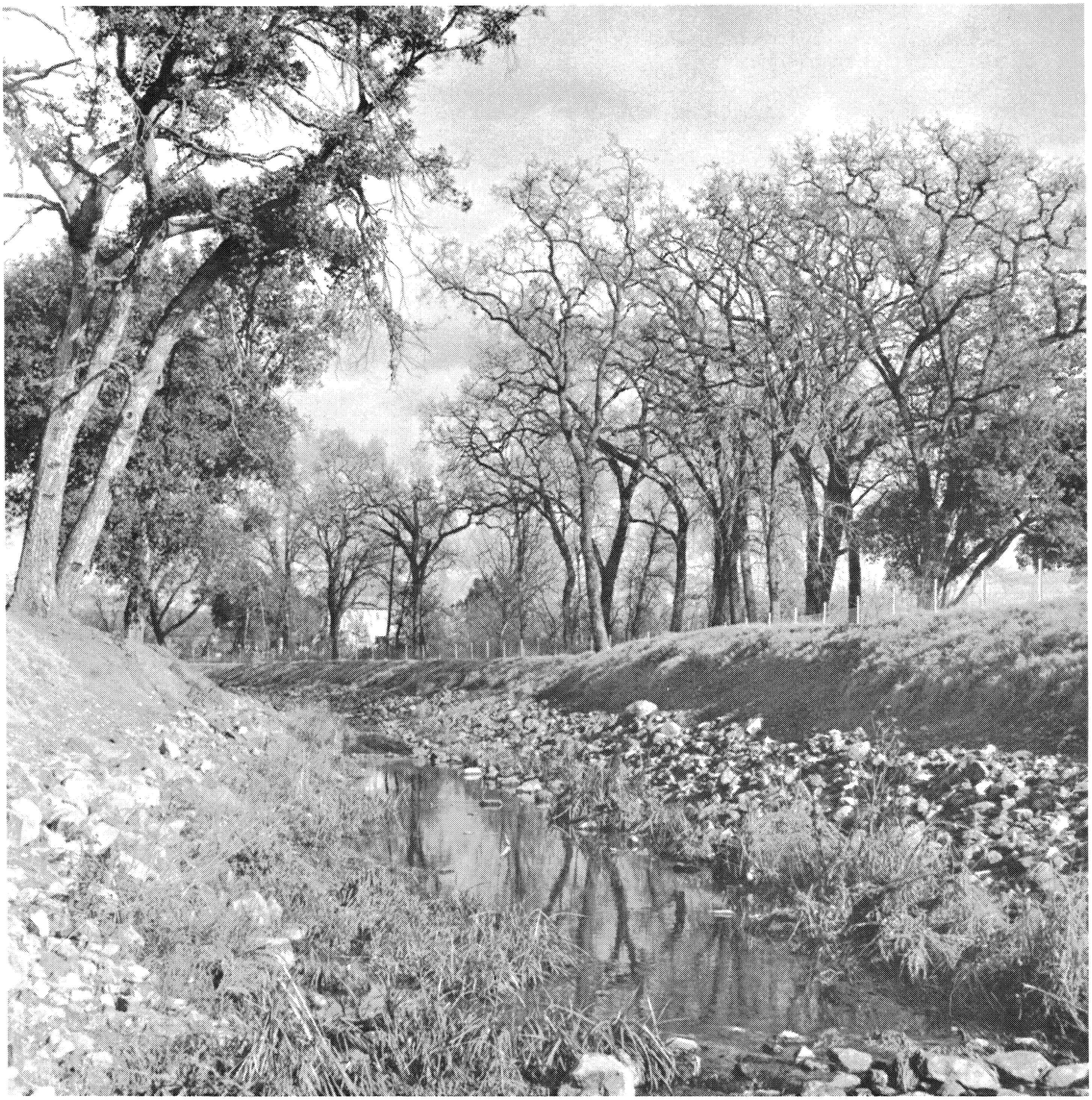
FLOOD CONTROL DESIGN CRITERIA



SONOMA COUNTY WATER AGENCY

SANTA ROSA, CALIFORNIA

SONOMA COUNTY WATER AGENCY

FILE:ZN/0-019

March 29, 1999

RE: DRAINAGE REVIEW CLARIFICATIONS

The Sonoma County Water Agency's (Agency) *"Flood Control Design Criteria*" manual was written some years ago. As a result, it tends to be out of date on a few items.

In the interest of making the design review process more efficient for both the Agency and the consultants, the following clarifications will be useful.

1. Where plastic pipe is being used, an n-value of 0.012 shall be used for design purposes.

2. The runoff coefficients shown on Plate No. B-1 (*Flood Control Design Criteria*) may not be accurate for lots under ¼-acre and ¼- to ½-acre due to the use of smaller lots with relatively large homes. It is suggested that the runoff factor "C" be calculated for developments where relatively large homes and small lots are used in lieu of using the Plate No. B-1 values.

   For vegetated areas, use the Plate No. B-1 curve for "Parks-Vegetated Areas - C_v." For other areas use a C-factor of 0.9 and follow the formula shown at the bottom of the plate to arrive at a composite C-factor for the development.

Sincerely,

Mark Lawler
Deputy Chief Engineer

rs3/u/cl/thausman/clarification

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SONOMA COUNTY WATER AGENCY

FLOOD CONTROL DESIGN CRITERIA MANUAL

for

WATERWAYS, CHANNELS and CLOSED CONDUITS

SONOMA COUNTY WATER AGENCY
SANTA ROSA, CALIFORNIA

November 1966
Revised April 1973
Revised August 1983

FOREWORD

The design criteria for waterways, channels and closed conduits herein contained have been adopted by the Sonoma County Water Agency for its own use in design of Agency drainage and flood control works, for the checking of design and construction of such projects which, upon completion, will be maintained by the Agency, and for checking design of private developments which are referred for review under agreement with other agencies. In the case of hydraulic review referrals performed under contract for other agencies, and if maintenance will be under their control, those agencies' structural and material standards will take precedence over this Agency's standards and this Agency's comments will be advisory only.

These design criteria have been adopted based upon experience on the part of the Agency and sampling of experiences of other like agencies throughout California. In view of the large backlog of experience represented within these standards, it is believed that adherence to the minimum requirements contained herein will provide the Sonoma County Water Agency, the County of Sonoma and cities in the County, a system of drainageways which will adequately carry off storm and drainage water.

It is important that drainage improvement projects enhance the environment. Vegetation, planted or natural, along a waterway enhances both the aesthetic and wildlife resources. As development encroaches on open space, vegetation along waterways becomes essential as refuge and nesting areas for birds and small animals. It may be advantageous not to channelize a drainageway, but to restrict development within the flood plain.

The engineer is invited to be as creative as possible and still provide a functional, safe and aesthetically pleasing waterway which is compatible with the environment.

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APPENDIX

CHAPTER I

GENERAL

It is the general purpose of these design criteria that waters generated by storms, springs, release from reservoirs, or other sources, be carried through the system of waterways and conduits within Sonoma County in such a manner that existing or projected building sites will be free from flood hazard in all flood events up to and including a flood of magnitude which is equaled or exceeded once in one hundred years. Flood hazard is defined as potential damage by water having sufficient depth or velocity to damage improvements or to deposit or scour soil other than within channels.

Unless an individual project requires diversion of water to conform to a comprehensive drainage plan, the water shall be received and discharged at the locations which existed prior to installation of the project and as nearly as possible in the manner which existed prior to construction of the project. Should diversion be required, sufficient work shall be done upstream and/or downstream to provide affected properties at least the same level of flood protection as existed prior to the diversion.

Construction of works by separate reaches of a waterway is discussed in appropriate sections of Chapters V through VIII. Construction of an improved waterway by reaches as controlled by economic and environmental factors or the state of use of adjacent lands is often necessary. Adjoining reaches of a waterway may, in some cases, remain for a period of several years before modifications are initiated in them. In cases of construction of modified waterways by reaches, interim construction upstream and downstream of the modified reach will generally be necessary to assure proper functioning of the modified reach and to avoid undesirable erosion or other effects in the adjacent unchanged reaches. Interim construction, insofar as possible, should be compatible with the full modifications which would ultimately be required.

This design manual is intended to provide general and some detailed design criteria. Most design details are left to the responsibility of the design engineer and may be handled by following good engineering practice. Material and construction specifications are not included, however, the Standard Specifications used by the Agency for materials and construction are listed in the references contained in the Appendix as an example of such specifications which may be utilized to good advantage in conjunction with these design criteria.

The design criteria contained herein are minimal and alternates thereto will be approved, provided such alternates are to a higher standard than those set forth herein. Exceptions to these design criteria may be allowed by the Agency when it can be determined that such exceptions are in the best interest of the public and the alternate will equal the normally accepted method.

These design criteria are intended to apply to waterways where continuous maintenance is necessary to insure adequate capacity to carry drainage and storm flows. In precipitous areas where streams have very steep gradients and are contained in ravines or canyons, the possibility of obstruction of streams to a degree which would cause flooding is generally remote. For waterways in such areas, hydraulic modification is generally not required. In the event that modification of waterways in precipitous areas coming under the jurisdiction of the Sonoma County Water Agency is deemed necessary or advisable, design of such waterways shall have the purpose of eliminating flood hazard except for flood events occurring less frequently than once in one hundred years. Design of such waterways shall conform to good engineering practice and shall be subject to the approval of the Chief Engineer; however, some deviation from the criteria of the chapters of these design criteria on Hydraulic Design, Alignment, Sections and Bank Protection, and Structural Design may be necessary or advisable.

CHAPTER II

CLASSIFICATION OF WATERWAYS

A. General:

A waterway is defined as any natural or arti icial channel or depression in the surface of the earth which provides a course for water flowing either continuously or intermittently.

Waterways coming under the jurisdiction of these design criteria shall be classified as defined below. A waterway may be subdivided into reaches, each of which may be of a different classification; however, each reach of a waterway so subdivided shall be of a length which is reasonable for the classification designated. Bridges and short culverts for channel crossings are not considered as channel reaches. Hydraulic design of such structures is discussed in the appropriate chapter of this manual.

Waterways are also designated as being major, secondary, or minor, based on the area of the tributary watershed as discussed in Chapter III of this manual.

B. Natural Waterways:

Natural waterways which have sufficient waterway area to contain design discharge within the design limits stated in Chapter IV and which have proved to be reasonably stable, and which are endowed with significant natural beauty, may be left natural and, if left natural, are classed as natural waterways. Other natural waterways endowed with significant natural beauty which contain only slightly inadequate waterway area or which are unstable only at infrequent locations, may also be classed as natural waterways, provided that minor channel modifications are made which render the waterway adequate and stable. Such minor channel modifications shall be of such character as to preserve substantially the natural features of the waterway, or the waterway shall be classified under Sections C, D or E herein-below or as a constructed natural waterway. A constructed natural waterway may be constructed as an alternate to other facilities or when the existing channel cannot be classified as a natural waterway.

Natural waterways and constructed natural waterways, as herein defined, shall be delineated by rail fence or other architecturally designed fence or marking which is permanent and is easily recognizable as delineating the right-of-way.

FIG. 2-1

NATURAL CHANNEL
BEFORE CLEARING

FIG. 2-2

NATURAL CHANNEL
AFTER CLEARING

C. Landscaped Constructed Waterways:

A landscaped waterway may be constructed from an existing waterway which cannot be classified as a Natural Waterway under Section B, but for which landscaping, planting or other aesthetic treatment may be desirable to enhance the appearance of the waterway and the livability of adjacent areas. Landscaped constructed waterways shall be designed in accordance with all provisions of these design criteria applicable to constructed open channels. Landscaping, planting, irrigation systems and other aesthetic treatment shall be designed for minimum maintenance and for minimum danger to the general public from hazards inherent in open channels. Plant materials and arrangements thereof shall be substantially in accordance with the recommendations contained in Reference 6 in the Appendix, unless otherwise approved by the Chief Engineer.

FIG. 2-3

EARTH CHANNEL
VELOCITY UNDER 6 FEET PER SECOND

FIG. 2-4

CONSTRUCTED CHANNEL
PRIOR TO INSTALLATION OF LANDSCAPING

Landscaped constructed waterways may have right-of-way delineated as described under Natural Waterways.

D. Closed Conduits:

Waterways whose design discharge may reasonably be conveyed in a 72-inch diameter or smaller concrete pipe shall be placed underground in a closed conduit, except for natural waterways, landscaped constructed waterways, and allowable gutter or roadside ditches.

The discharge as calculated by use of the method contained in Chapter III will be used to determine whether a waterway shall be modified as a constructed channel or as a closed conduit, even though the waterway may actually be designed to convey a discharge larger than that so calculated.

E. Constructed Channels:

All waterways which cannot be classified under Sections B or D are classed as constructed channels.

CHAPTER III

HYDROLOGIC DESIGN

Hydrologic design shall be predicated upon ultimate development of the tributary watershed. Valley areas and gently to moderately sloping uplands, which are undeveloped at the time of design, shall be assumed to be fully developed as single and two family residential zones (lots under 1/4 acre in size) unless a publicly proposed development, precise zoning, or the General Plan indicates a different land use. Areas of steep terrain shall be assumed to be developed fully to an intensity of use compatible with the nature of the terrain; such use may be for residential development in lots larger than 1/2 acre, unless precise existing zoning or the General Plan indicates a different use. Steep terrain is defined as terrain whose general average slope is in excess of 20 percent. Undeveloped areas whose average ground slope is between 15 and 20 percent may be assumed as being developed into residential subdivisions with lot size of 1/4 to 1/2 acre, unless existing development, existing zoning or the General Plan indicates a different use.

Public parks, public golf courses and other publicly owned areas may be considered as vegetated to the extent that they are actually vegetated, unless publicly proposed plans show that the body having jurisdiction intends to alter the existing use of the area so as to make the surface less pervious.

Average recurrent interval is defined as the average number of years, over a long period of time, in which a given flood event is equaled or exceeded in magnitude of discharge.

Flood flows to be used for the design of waterways, channels and closed conduits shall have minimum average recurrence intervals as follows:

1. Major Waterways have a drainage area of four square miles or more and shall be designed for an average recurrence interval of 100 years.

2. Secondary Waterways have a drainage area of between one and four square miles and shall be designed for an average recurrence interval of 25 years, except as hereinafter provided.

3. Minor Waterways have a drainage area of one square mile or less and shall be designed for an average recurrence interval of 10 years, except as hereinafter provided.

A given waterway, therefore, will be classed as minor in its upper reaches, then change to the secondary classification at a point where the drainage area exceeds one square mile, and then change again to the major classification at a point where the drainage area exceeds four square miles.

Those waterways set forth in a comprehensive drainage plan of the Agency shall be designed and constructed to carry the discharge of water indicated in such a plan.

Those waterways on which stream gaging stations have been maintained for a sufficient time and for which factors are available to convert historic streamflow into streamflow based upon projected development of the watershed shall be designed to carry the flows statistically predictable.

For all other watersheds, design discharge shall be determined by the use of the rational formula:

$$Q = C\ I\ A\ K$$

in which:

Q = design discharge, cubic feet per second

C = runoff coefficient (from Plate B-1 in the Appendix, based upon ultimate development)

I = intensity of rainfall, inches per hour (from Plate B-2 in the Appendix)

A = tributary watershed area, acres

K = K factor (from Plate B-4)

Time of concentration shall be based on an initial time of 7 minutes for commercial or similar areas, 10 minutes for lots smaller than 1/2 acre, and 15 minutes for lots of 1/2 acre and larger.

Most watersheds are too large for application of the rational method in one step. In that case, the waterway shall be subdivided into reaches of reasonable length and the rational formula applied to each reach step by step, properly accumulating the parameters. The initial reach for rational method hydrology must be consistent with the initial area (not more than 2 acres) and concentration time chosen by the designer. See sample drainage computations in the Appendix.

CHAPTER IV

HYDRAULIC DESIGN

A. GENERAL:

For the solution of hydraulic design problems commonly encountered, reference may be made to the bibliography contained in the Appendix or other generally accepted references. For those uncommon design problems not susceptible to solution by reference to the bibliography, the design engineer shall provide such reference, treatise, model study report, or prototype test as is necessary to confirm his hydraulic design.

Secondary or minor waterways outletting into major or secondary downstream waterways shall be designed to operate against a 25 or 10 year flow respectively in the major or secondary downstream waterway, provided that the ground elevation along the secondary or minor system shall be above the 100 year water surface elevation in the major or secondary downstream waterway.

If a secondary or minor waterway is placed in a closed conduit, sufficient additional surface routes for flood flows shall be made available to carry the added flow increment up to the 100 year design discharge with no more than nuisance damage to improvements or projected improvements and with no inundation of present or future buildings. If such surface routes cannot be made available, the secondary or minor waterway shall be designed to carry the 100 year design discharge.

Design depth of flow in gutters shall not exceed 0.4 foot for the 10 year flow. Roadside ditches, when allowed, shall not be used where the design flow is greater than that which could be carried in a standard gutter flowing 0.4 foot deep on the same slope as the road profile slope. Where the discharge exceeds gutter capacity, a closed conduit system shall be provided. Roadside ditches shall be designed so that the water surface for the design discharge will be at or below the outside edge of the road shoulder such that there is no flood water in the normal travel-way of the road and below adjacent ground level.

B. MANNING'S "n" VALUES:

Manning's "n" values for design shall be as follows:

1.	Concrete, steel troweled or smooth-form finish	n = .013
2.	Concrete pipe, precast or cast-in-place	n = .014
3.	Concrete, wood float or broomed finish, including pneumatically applied mortar	n = .015
4.	Asphaltic concrete	n = .017
5.	Corrugated metal pipe (non-spiral)	n = .024
6.	Sack concrete riprap	n = .030
7.	Grouted rock riprap	n = .030
8.	Loose rock riprap	n = .035
9.	Grassed channels:	
	a. For VR greater than 20	n = .035
	b. For VR less than 20	(From Reference 4)
10.	Constructed Natural Waterways	n = .050 Minimum

For natural channels, vegetated swales, or cases not covered above, "n" values shall be determined from References 4 or 12. For materials other than stated above, "n" values may be accepted if developed and specified by the State of California and/or by an independent test performed by a reputable organization.

C. <u>OPEN CHANNELS:</u>

Constructed open channels and waterways shall be designed to carry the quantity of flow determined as set forth in Chapter III with minimum freeboard between design water surface and the top of bank of 1.50 feet or 0.2 of the specific energy, whichever is greater. Where this minimum freeboard does not provide the necessary differential head to allow adequate gravity drainage for projected development of the tributary areas, the design water surface shall be lowered sufficiently to allow such areas to drain to the channel by gravity, except where levees are permitted. Levees are generally unacceptable; specific exception to allow levees may be granted in tidal areas or in other situations of extreme difficulty only after a specific determination by the Chief Engineer that the proposed levee is the only feasible method of providing adequate flood protection.

For natural waterways and constructed natural waterways, design flow may be allowed in an overflow area above the defined banks provided, however, the flow must be contained within a defined overflow area and freeboard provided as specified above between the water surface and adjacent ground elevation or finished grade elevation within lots or areas in which improvements are to be constructed. Less than 1.50 feet freeboard may be considered for small natural swales and creeks through open space such as parks and golf courses. In any event, freeboard shall be adequate to provide for reduced capacity due to weed growth and 100 year flow within the right-of-way.

Prior to computing the required freeboard, super-elevation of the water surface on curves shall be determined by use of formulas contained in Reference 1 or 2 or the formulas listed in Plate B-5 in the Appendix and the design water surface adjusted therefor. Open channels shall not be designed with a slope in the range of plus or minus 20 percent of critical slope unless added freeboard for instability waves is provided, as determined from the formula listed in Plate B-5 in the Appendix. Channels designed for supercritical flow shall have their sequent depth below top of bank.

Channels shall be designed taking into account the energy losses due to existing and projected road crossings or other obstructions to be placed within the channel. Energy losses for bridge piers, interior walls in multiple box culverts, or other obstructions within the channel, shall be predicated upon the entrance obstruction width plus 2 feet of debris allowance on each side of each obstruction. For bridge piers or multiple box culverts, in lieu of the 2 feet of debris allowance on the full height of the pier or interior walls, such piers or walls may be extended upstream on a 2 to 1 downward slope to the channel invert. A debris width of 2 feet on each side of the downward sloping wall shall be considered for the upper quarter of the bridge or culvert depth except that the minimum height of debris shall be 2 feet. In lieu of debris allowance at small pipes and groups of small pipes, a flared entrance section or a debris trap must be used.

Bridges, culverts, and utility crossings which span major and secondary open channels and which are existing, planned or projected at the time of channel design shall have a minimum clearance from soffit to design water surface of 1.0 foot and shall cause no encroachment on the specified minimum freeboard in the upstream channel or waterway. Channels shall be designed with proper allowances for hydraulic losses for all such planned or projected future crossings to maintain clearance and freeboard as specified above. In the case that a crossing is proposed over an existing channel where the hydraulic effect of the crossing was not considered in design of the channel, minor encroachment on freeboard may be permitted provided that it can be shown that such encroachment would not adversely affect gravity drainage of adjacent tributary areas. Modification of the existing channel and special attention to the design of piers or other obstructions placed in the channel may be required to keep any encroachment on freeboard at an acceptable magnitude.

The water surface profile shall be computed and plotted through all crossing structures. Culverts of all types providing crossings of minor waterways shall be designed hydraulically in accordance with entrance criteria contained in Section D for minor waterway closed conduit systems.

Constructed natural waterways shall be excavated as required to pass the design discharge under interim and ultimate conditions of natural plant and tree growth and of other natural channel characteristics. Trees and other plants and grass shall be planted as a part of initial construction to promote and encourage ultimate natural appearance. Willows and other phreatophytes shall be planted along the low flow water line as a part of initial construction.

The ultimate constructed natural waterway shall satisfy the freeboard requirements in this Chapter. The constructed natural waterway may be utilized in any situation where right-of-way space can be provided and temporary unvegetated appearance can be tolerated prior to growth and generation of natural amenities.

The following sequence of typical conditions is presented so as to describe a typical process of developing a natural waterway following initial construction and planting described above.

> <u>First through Fourth Year</u>: Water plants such as cattails, tules and others will normally propagate naturally in the low flow and ponded portions of the channel. This growth will be allowed to remain to the extent necessary to provide habitat for stream-oriented wildlife.

FIG. 4-1

CONSTRUCTED NATURAL WATERWAY
NEWLY CONSTRUCTED

FIG. 4-2

CONSTRUCTED NATURAL WATERWAY
POST CONSTRUCTION, PRIOR TO TREE GROWTH

Fifth to Twentieth Year: The phreatophytes will have begun to dominate and shade out cattails and water plants early in this period, causing a natural decline in that type of growth. The natural habitat will be re-established and the appearance will be enhanced by large willows and other fast-growing trees and plants. The oaks or other more permanent trees will be well established, but will not yet be a dominant feature of the waterway until the later stages of this period.

FIG. 4-3

CONSTRUCTED NATURAL WATERWAY
8 TO 10 YEARS AFTER CONSTRUCTION

Twentieth Year and Beyond: The oaks and other large natural growth will have become a dominant part of the natural channel growth, causing a decline in growth of phreatophytes. After the twentieth year, evidence of original constructed excavation of the channel to gain flood-carrying capacity will be, to a large extent, obliterated by growth, stream meanders, siltation and erosion. From this point on, continuing dynamic natural forces will mold the channel shape and appearance on an ever-changing basis.

FIG. 4-4

CONSTRUCTED NATURAL WATERWAY
15 TO 20 YEARS AFTER CONSTRUCTION

The ultimate condition of the constructed natural waterway will be a result of continued maintenance, which would preclude encroachment of structures from adjacent properties and would allow all natural forces to continue except for two necessary restraints:

1. The density of growth would be limited in the flood-carrying portion of the constructed natural waterway such that the design storm would not flow deeper than originally designated.
2. The channel portion of the constructed natural waterway would be restrained if erosive forces tended to carry the channel outside the right-of-way originally reserved.

D. CLOSED CONDUIT SYSTEMS:

Major and secondary waterways placed within a closed conduit system shall have a minimum 1 foot clearance between the design water surface and the soffit of the conduit. The design depth in circular conduits shall not exceed 0.80 of the diameter of the conduit for major and secondary waterways. Minor waterways placed in closed conduit systems may be designed for full conduit capacity and, if necessary, pressure flow. The hydraulic entrance condition at a closed conduit minor waterway shall be such that the 10 year discharge will have the specified freeboard in the upstream channel or waterway and that the 100 year discharge will be contained within the banks of the upstream waterway or within drainage easements. The entrance to the closed conduit minor waterway may be submerged provided that the above criteria are satisfied. At inlets and non-pressure type manholes within a closed conduit system, the hydraulic gradeline shall be not less than 1 foot below the gutter or inlet surface elevation or such that free weir flow will be assured at inlets. At locations where conduits are stubbed out for future extension, the design hydraulic gradeline shall be low enough to allow proper drainage of the tributary area, with a minimum of 1.5 feet below general existing ground level. For conduits designed for supercritical flow, the energy gradeline shall not be above ground level at inlets and non-pressure type manholes.

Energy losses due to debris load caused by splitting flow at entrance to or within a closed conduit system shall be computed in the same manner as obstruction losses in open channels. In addition to normal friction losses, energy losses due to entrance and exit conditions, bends and transitions shall be computed and considered.

Velocities in conduits shall be a minimum of 2.5 feet per second to give a self cleaning action to prevent siltation.

CHAPTER V

ALIGNMENT

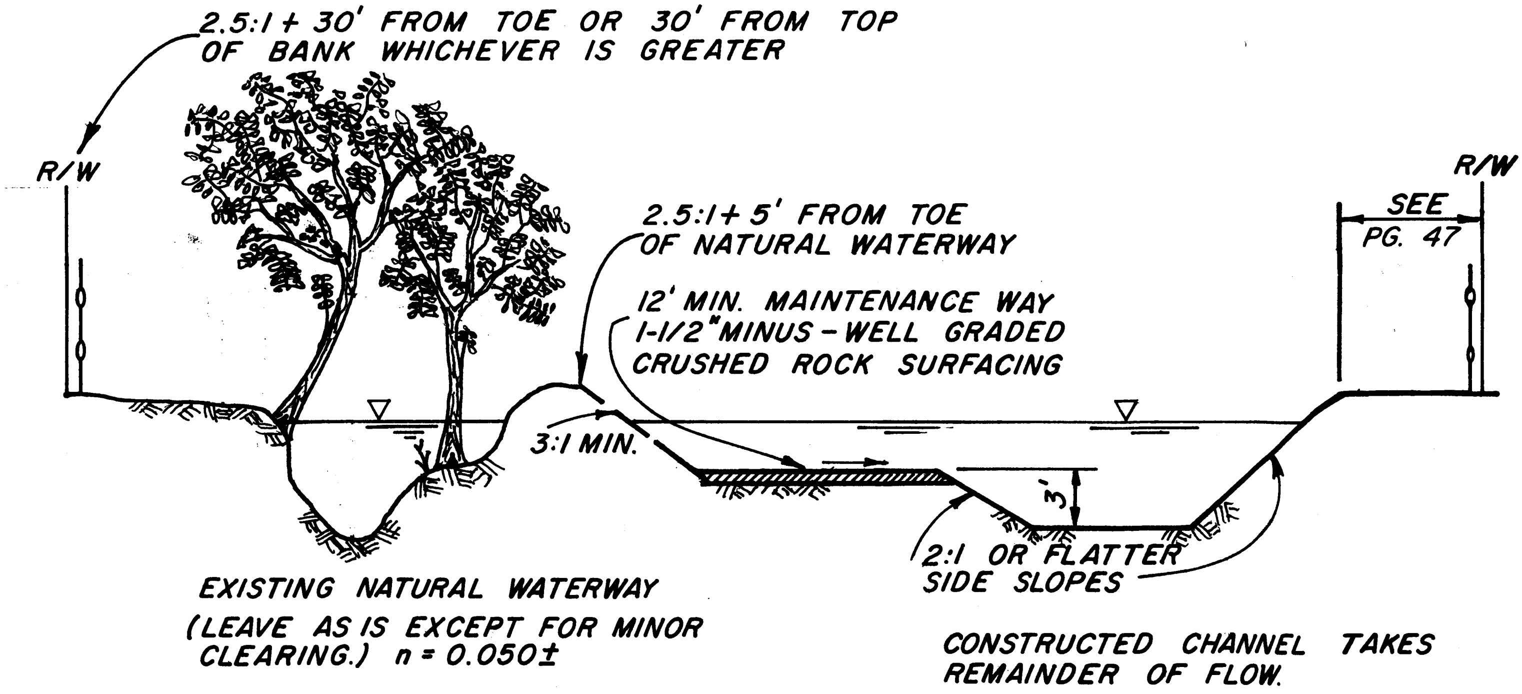
Constructed waterways generally will follow the existing waterway alignment except where bank stability, property boundary restraints or environmental factors dictate an alternative course.

Constructed waterways may be designed as a bypass facility with an alignment generally parallel to the meandering path of the existing creek. The existing waterway could carry a portion of the design flow and the bypass waterway would then carry the remainder of the design flow as shown on Pages 24 and 25.

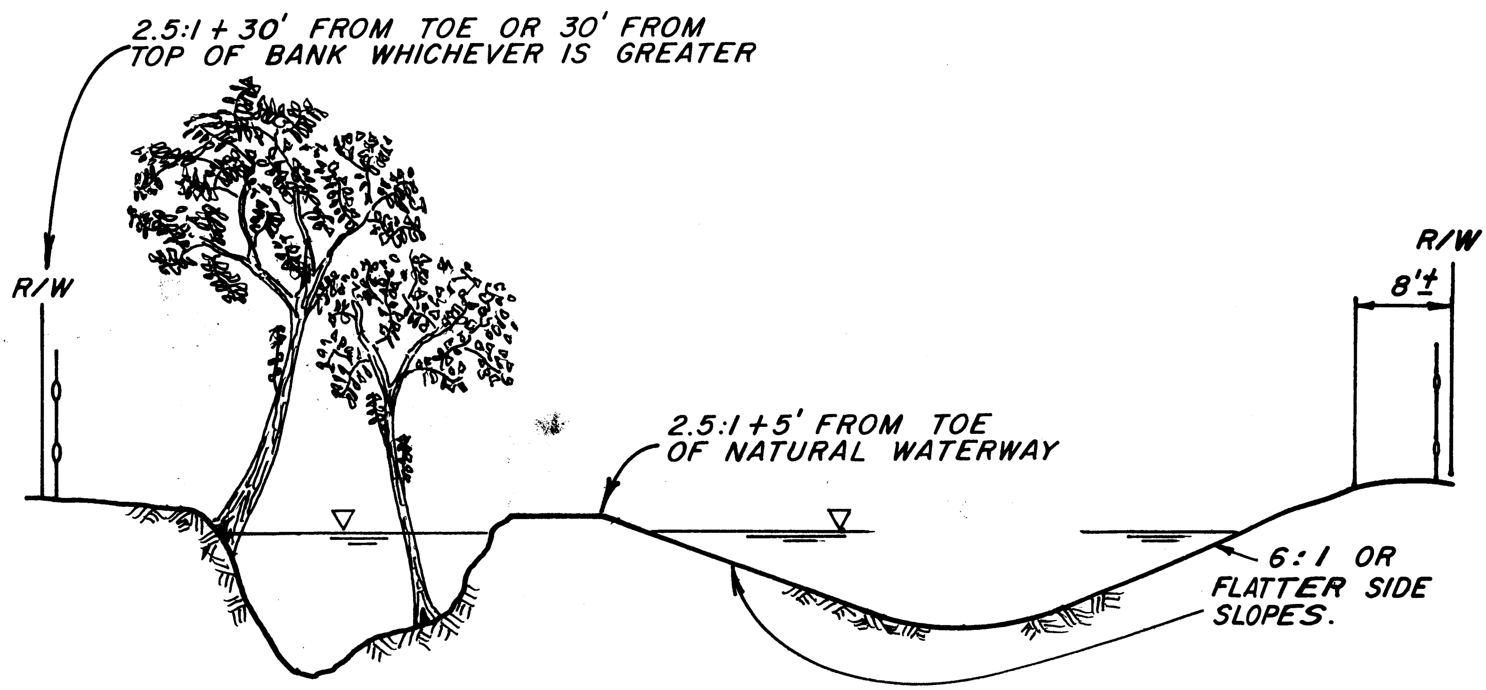
Both ends of a constructed waterway shall be aligned to conform the modified reach to the existing waterway in such a manner that the upstream and downstream waterways will not be altered by degradation, erosion or other undesirable effects.

Minimum centerline radii for curves in constructed waterways shall be three times the top width of the channel.

BYPASS SYSTEMS

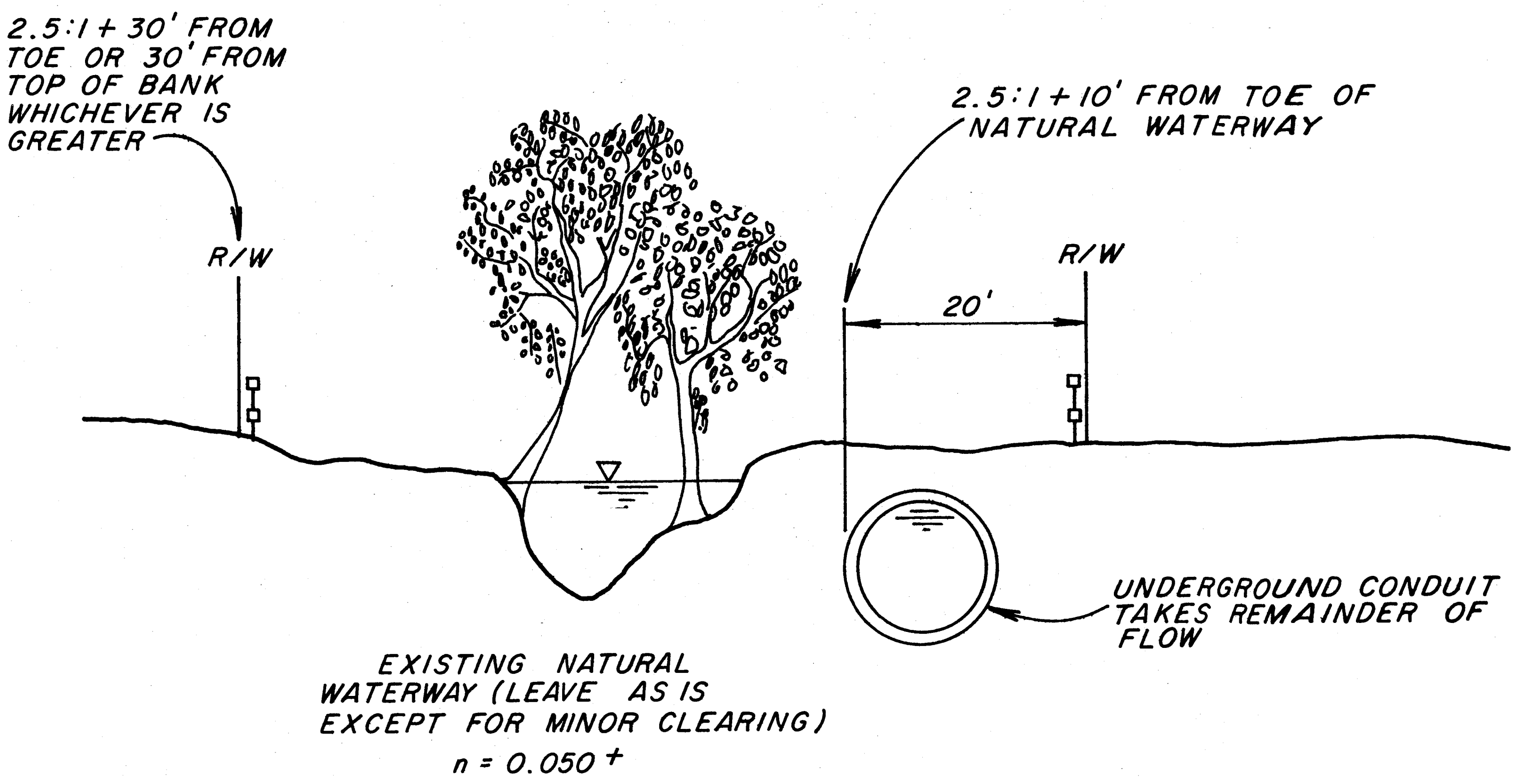


ALTERNATE 1



ALTERNATE 2

BYPASS SYSTEMS



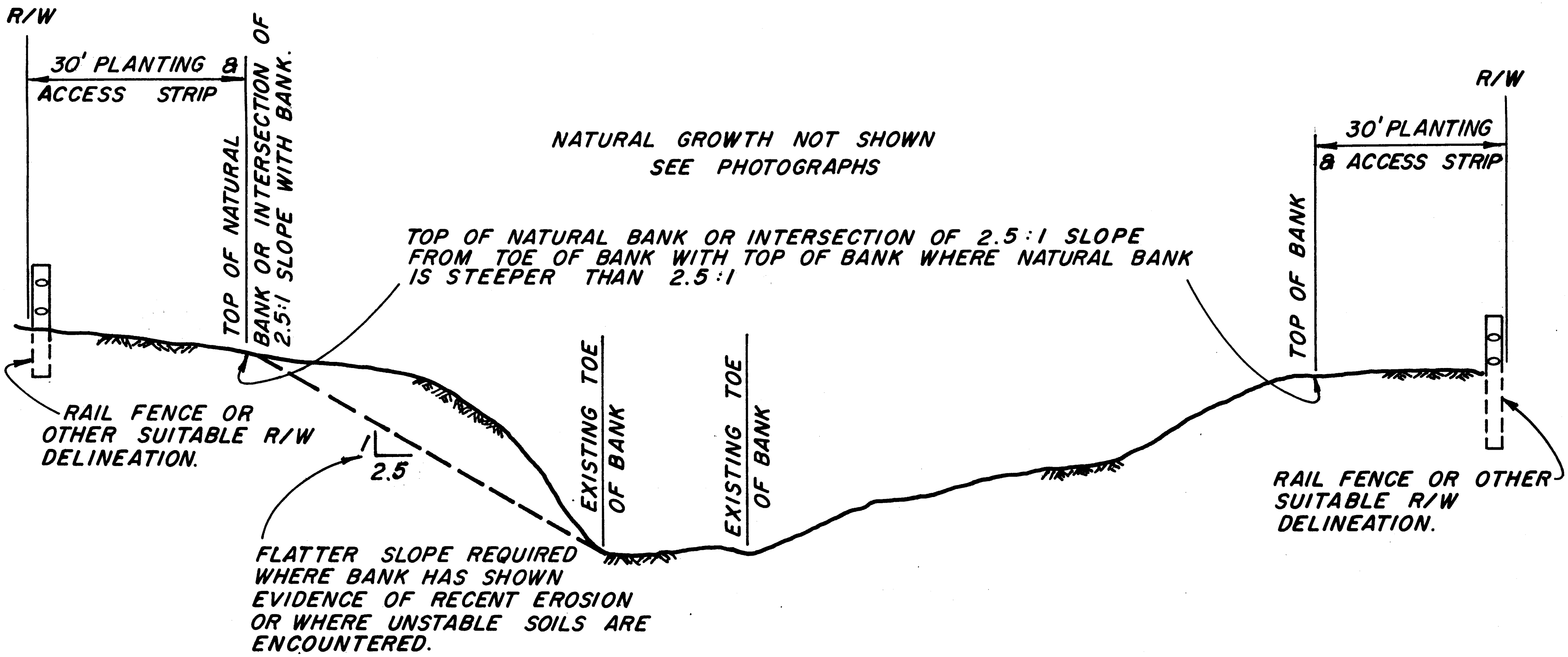
ALTERNATE 3

CHAPTER VI

SECTIONS AND BANK PROTECTION

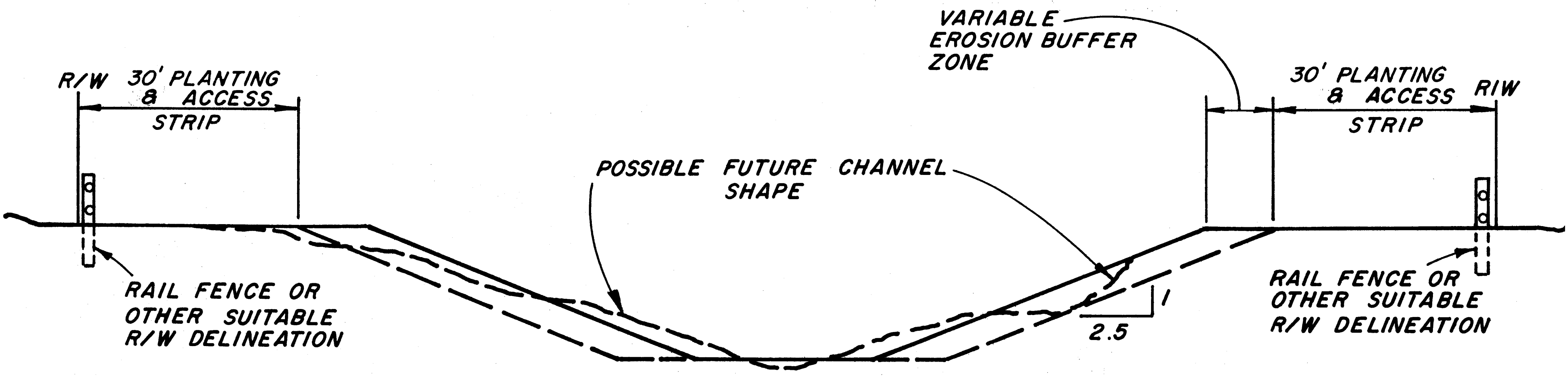
In certain reaches, the channel side slopes may need to be flattened to obtain stability in highly erosive soils or simply for aesthetic or public use value. Public use areas, such as parks or greenbelts, may be incorporated in the design of the waterway.

Bottom widths may vary as shown on Pages 27 through 32, depending on where the maintenance access is provided.



RIGHT OF WAY FOR NATURAL WATERWAY

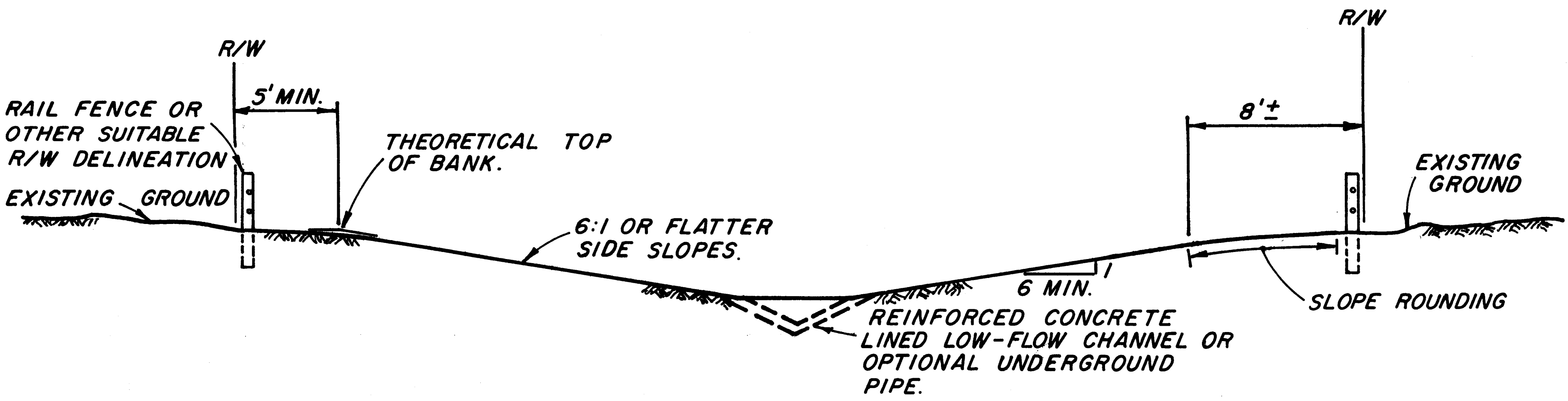
RIGHT OF WAY



RIGHT OF WAY FOR CONSTRUCTED NATURAL
WATERWAY

VELOCITY LESS THAN 6 ft/sec

NATURAL GROWTH NOT SHOWN
SEE PHOTOGRAPHS



FOR MAINTENANCE WAY, PROVIDE A 12' WIDE STRIP FREE OF TREES & SHRUBS ON A 6:1 OR FLATTER SLOPE.
THE MAINTENANCE WAY MAY BE LOCATED ANYWHERE WITHIN THE R/W ON 6:1 OR FLATTER SLOPE.

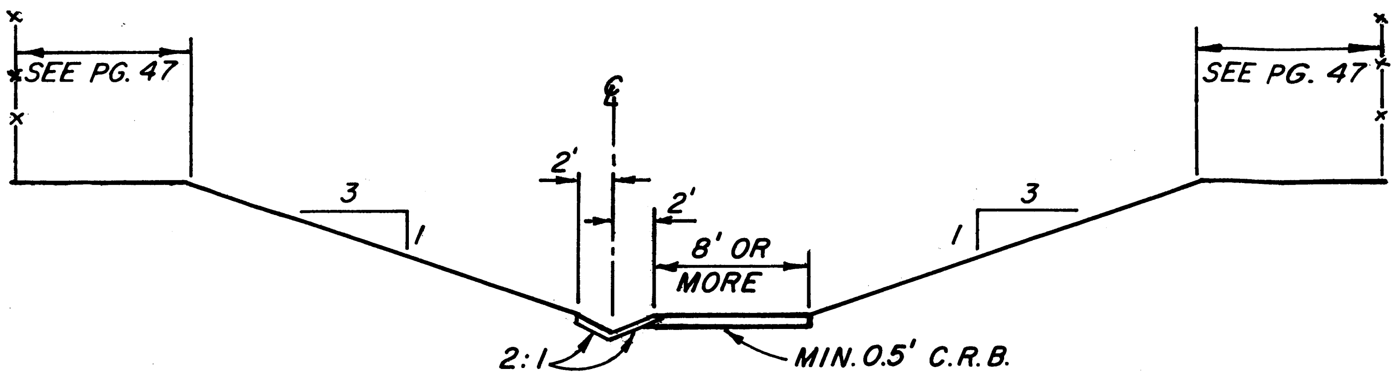
PLANTING: PLANT MATERIALS AND ARRANGEMENT SHALL GENERALLY FOLLOW THE GUIDELINES CONTAINED IN REFERENCE 6, AND AS A MINIMUM SHALL COVER THE AREA FROM THE DESIGN WATER SURFACE TO THE RIGHT OF WAY (R/W) LINES, EXCEPT FOR THE REQUIRED MAINTENANCE WAY.
EARTH PORTIONS NOT CONTAINING TREES OR SHRUBS SHALL BE TURFED.

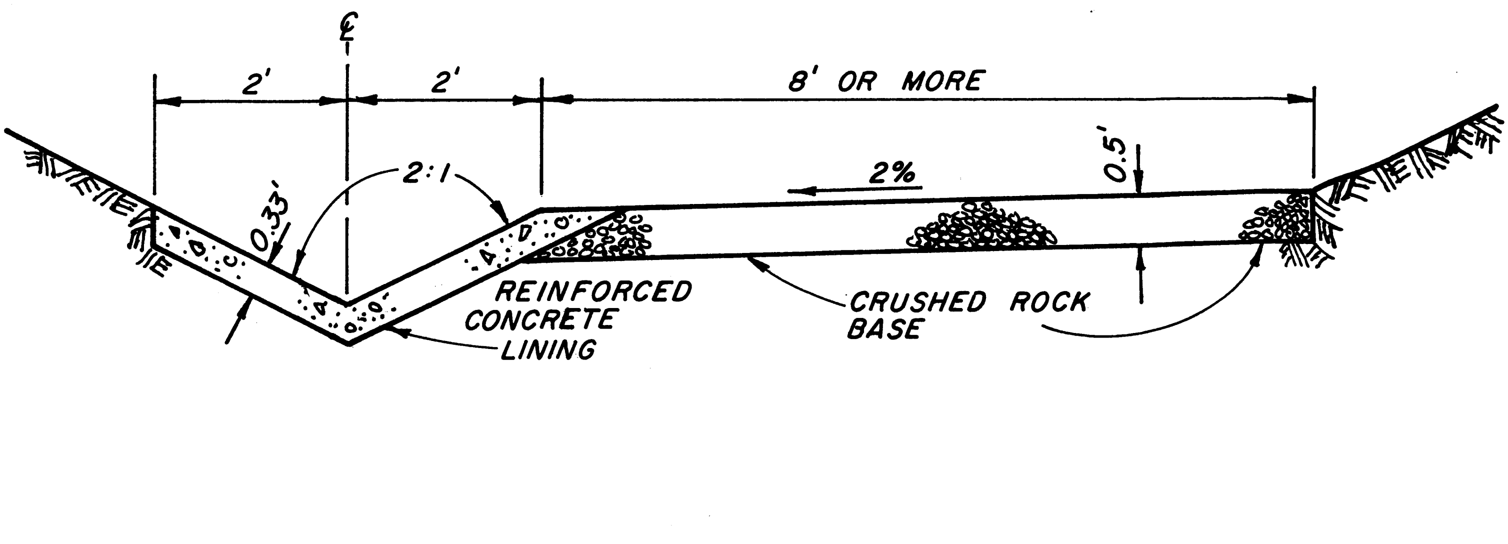
LANDSCAPED CONSTRUCTED WATERWAYS

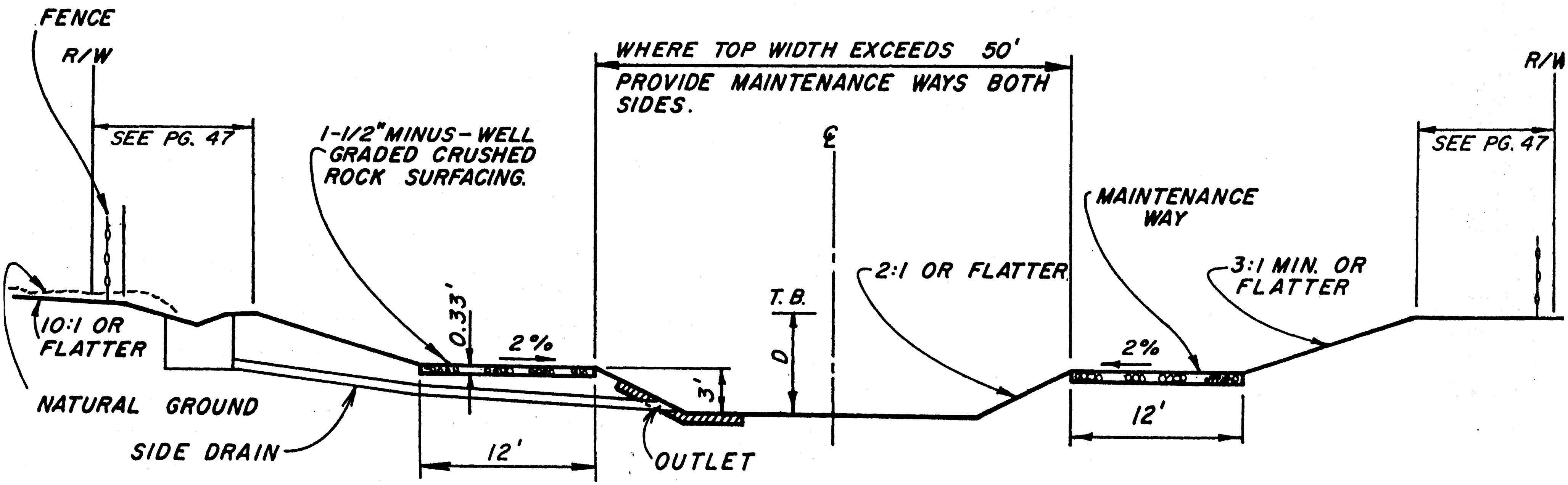
VELOCITY LESS THAN 6 ft/sec

MINIMUM RIGHT OF WAY FOR
CONSTRUCTED WATERWAYS

MINIMUM CHANNEL ALTERNATE



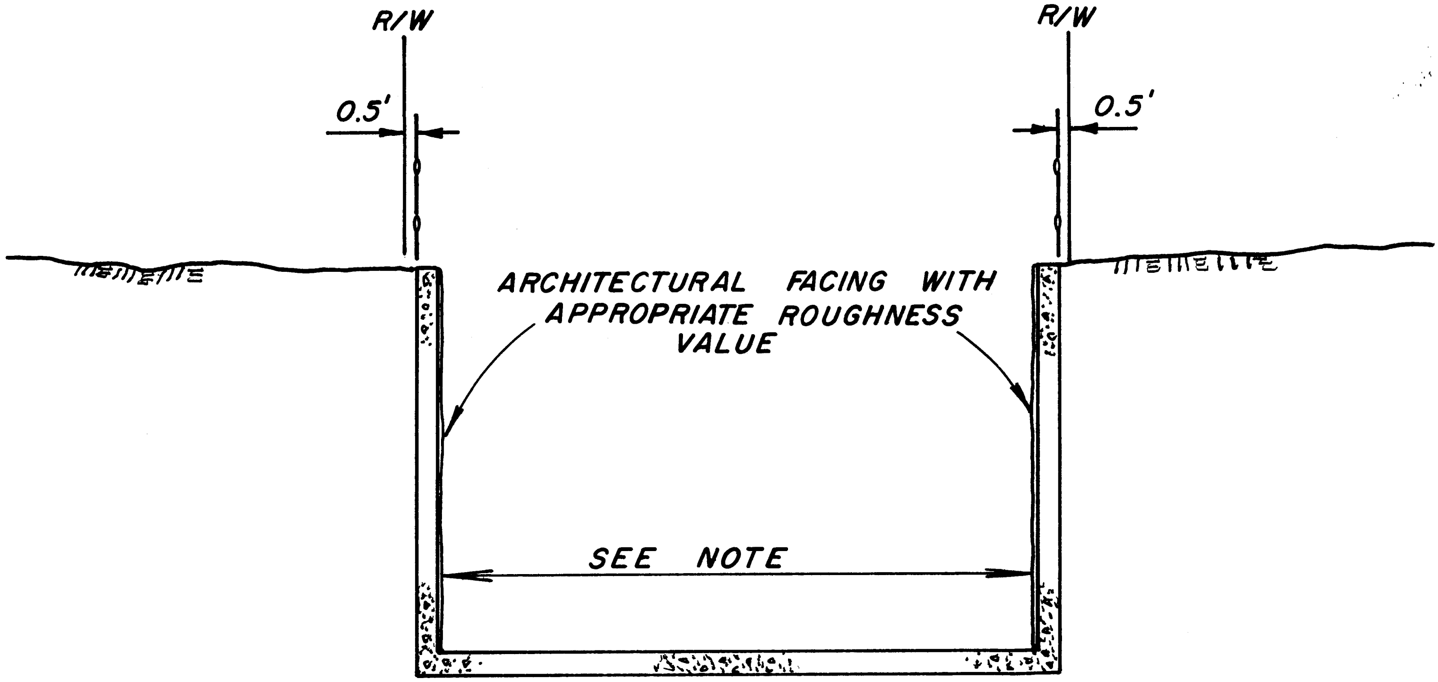




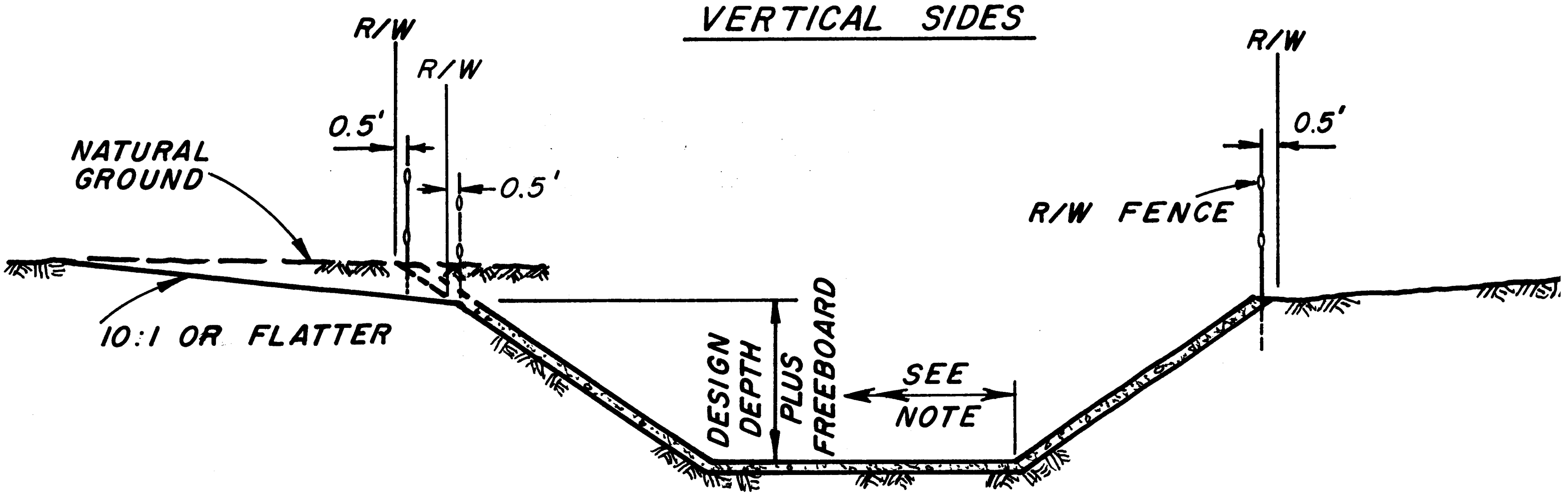
MINIMUM RIGHT OF WAY
FOR CONSTRUCTED WATERWAYS

50' TOP WIDTH OR WIDER

CHANNEL PROTECTION



VERTICAL SIDES



SLOPING SIDES

PROVIDE ACCESS FROM PUBLIC ROAD TO CHANNEL INVERT AT INTERVALS NOT TO EXCEED 2000'

NOTE: BOTTOM WIDTH SHALL BE A MINIMUM WIDTH OF 10 FEET OR TOP OF BANK ACCESS SHALL BE PROVIDED.

Side slopes may need to be protected with lining if the velocities are erosive. When concrete is used and the velocity in the concrete section is 6 feet per second or more, loose rock riprap shall be used as a transition strip above the concrete lining. If velocities dictate the necessity of channel lining, it shall consist of concrete, grouted rock riprap, Gabion type riprap, sack concrete riprap, or air-blown mortar. Grassed channels or loose rock riprapped channels shall have side slopes not steeper than 2 to 1. Lined channels shall have side slopes not steeper than 1.5 to 1 unless designed structurally to resist all lateral loads applied to the bank lining.

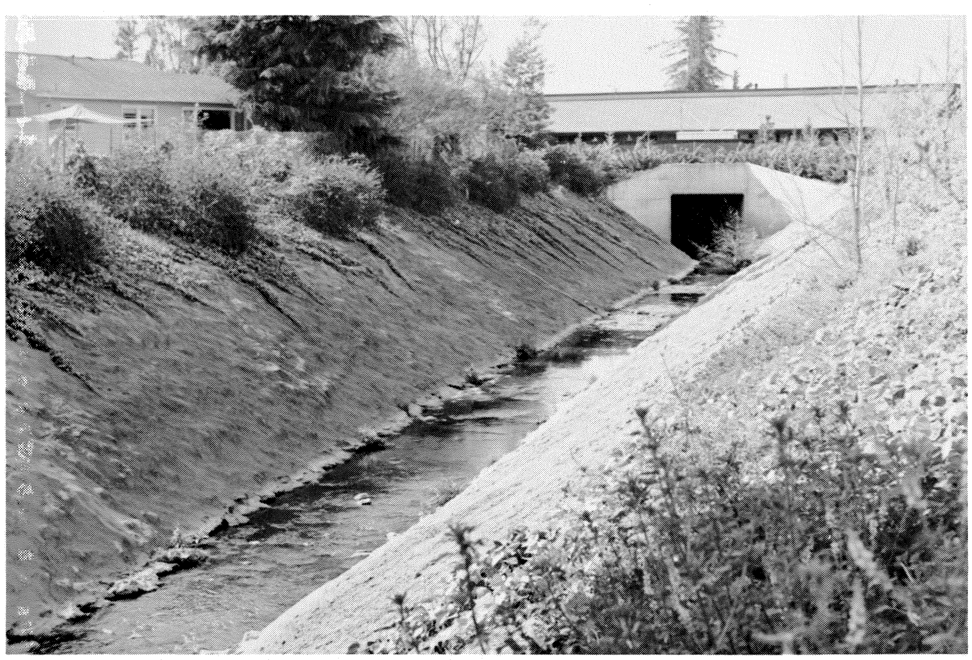


FIG. 6-1

CONCRETE CHANNEL
SLOPING SIDES

FIG. 6-2

CONCRETE CHANNEL
VERTICAL SIDES

Channels shall have flatter side slopes if soil instability appears probáble from field investigation. Design of slopes in unstable soils shall be predicated upon results of an investigation by a registered professional engineer qualified in soils engineering. The depth of constructed channels and waterways shall be sufficient to allow tributary closed conduits and other tributary waterways to properly outlet into the channel. Generally this will require a minimum channel depth of 5 feet.

Bank protection shall be provided in constructed channels and landscaped constructed waterways in accordance with the criteria shown on the drawings of typical sections on pages 29, 32, 36 and 37. Velocities referred to on the typical sections are, in each case, the mean velocity in the cross-section. The term "stress areas" as used on said typical sections means locations where the hydraulic stress is greater than in a straight, uniform channel reach, and includes junctions, transitions, and curves whose centerline radii are less than six times the width of the design water surface. Stress area protection shall extend downstream from the end of the stress area a distance equal to ten times the design water depth.

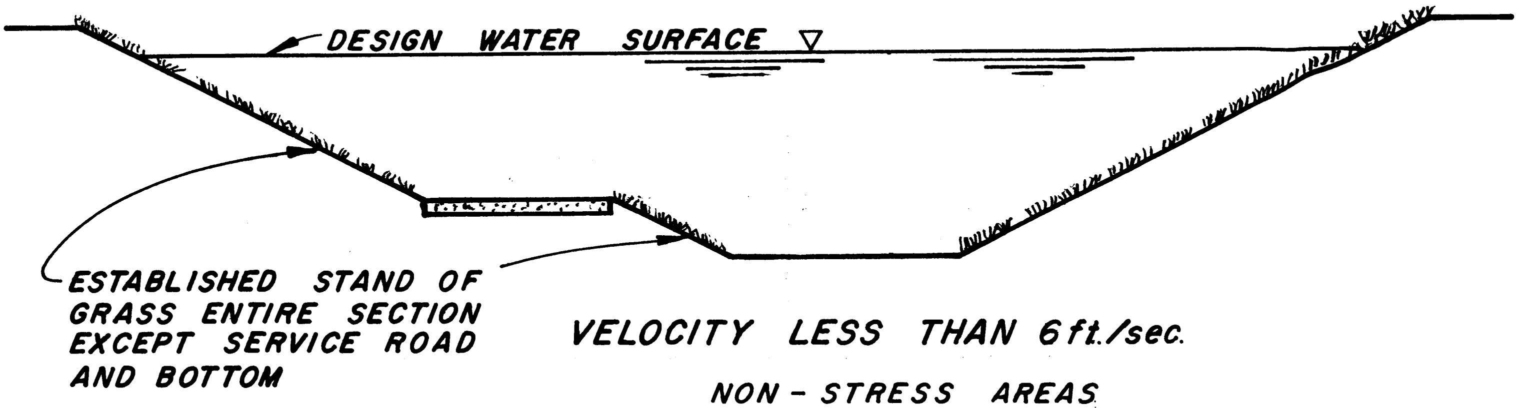
At drop structures or in other locations where a hydraulic jump may be formed, bank protection shall be provided downstream from the jump for a minimum distance of six times the sequent depth. This protection shall cover the channel invert and extend to the height of the sequent depth and may be either concrete, grouted rock riprap, sack concrete riprap, or air-blown mortar. A minimum distance of three times the design water depth shall be provided with loose rock riprap immediately downstream from the lined reach covering the same cross-section as required for the lining.

Any of the channel lining materials may be used for bank protection. Other acceptable materials for bank protection include the following:

1. Low-growing grass which will stay green under natural conditions in Sonoma County throughout the summer, and which will form a thick, dense turf.

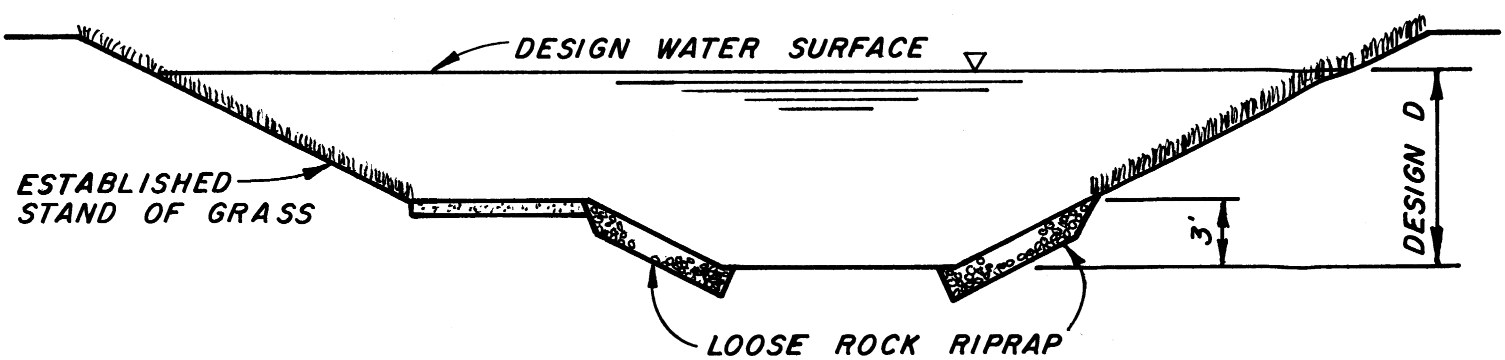
CHANNEL PROTECTION

FOR ALL CHANNELS EXCEPT NATURAL CREEKS AND CONSTRUCTED NATURAL CHANNELS



VELOCITY LESS THAN 6 ft./sec.

NON - STRESS AREAS

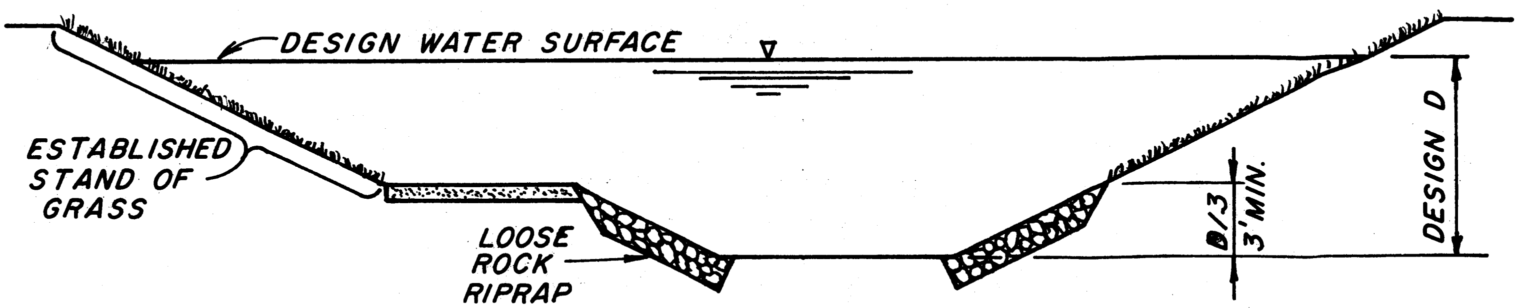


VELOCITY FROM 3ft./sec. TO 6 ft./sec.

STRESS AREAS

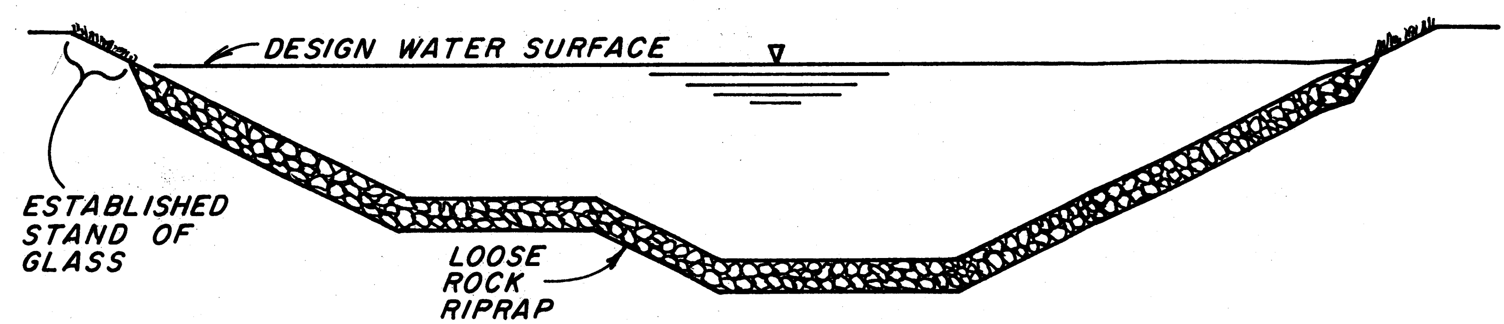
CHANNEL PROTECTION

FOR ALL CHANNELS EXCEPT NATURAL CREEKS AND CONSTRUCTED NATURAL CHANNELS



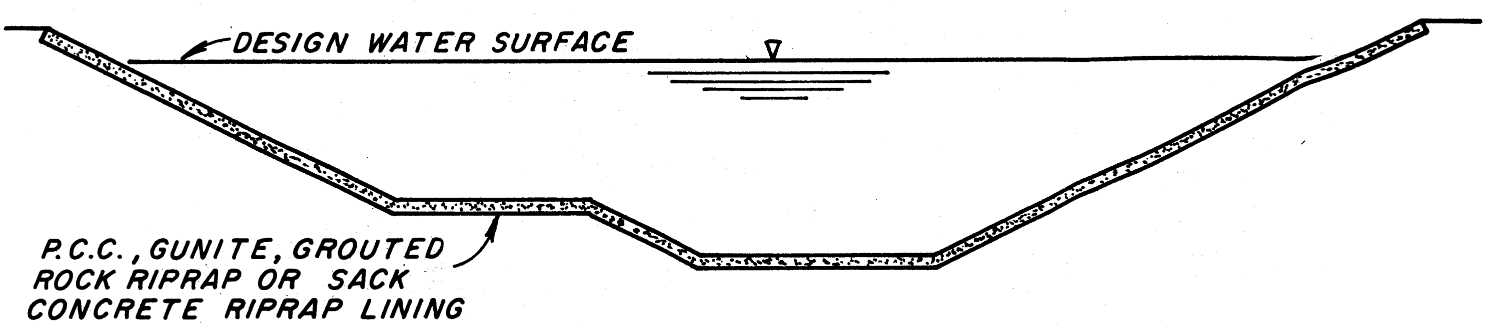
VELOCITY FROM 6 ft./sec. TO 10 ft./sec.

NON – STRESS AREAS



VELOCITY FROM 6 ft./sec. TO 10 ft./sec.

STRESS AREAS



VELOCITY GREATER THAN 10 ft./sec.

ALL AREAS

2. Loose rock riprap. Rocks shall be angular and well-graded from an average diameter of 4 inches to an average diameter of 15 inches with approximately 50 percent by weight smaller than 9 inches in average diameter. Not more than 10 percent of the rock riprap by weight shall be less than 4 inches average diameter. An occasional rock having an average diameter of not more than 20 inches may be included, provided that not more than 5 percent of the rock riprap area shall have these larger rocks projecting above the neatlines, but in any event the total rock mass shall be dense and well integrated. (See Figure 6-3)

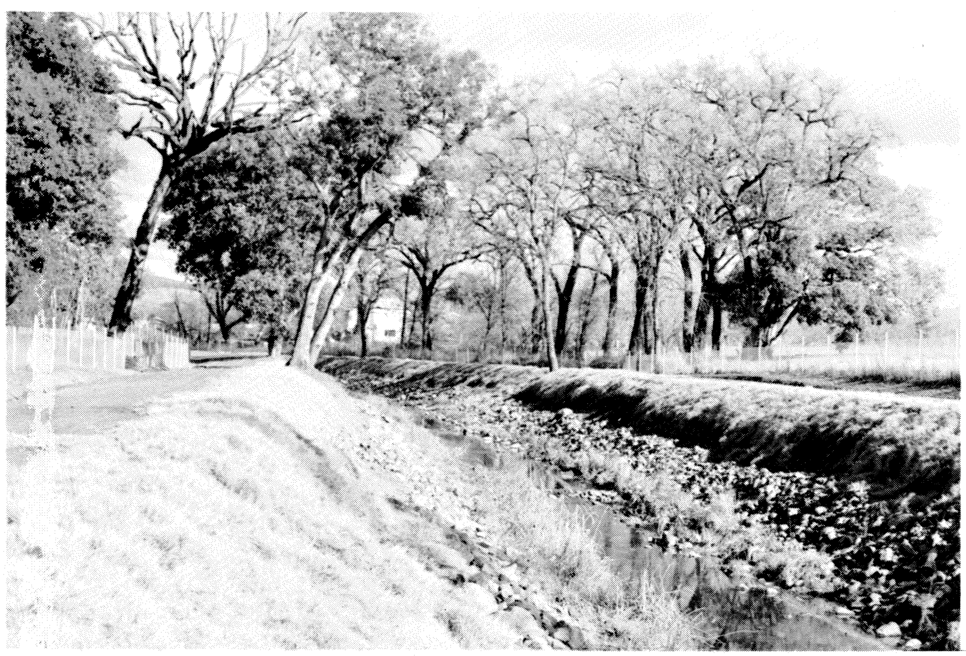


FIG. 6-3

EARTH CHANNEL

ROCK RIPRAP TO PROTECT TOE OF SLOPE

The limiting velocities shown on the typical sections apply to the usual cohesive soil conditions found in Sonoma County; lower limiting velocities may be applied to the design of channels constructed in non-cohesive soils.

For any velocity and hydraulic stress combination, the materials shown for a condition of higher velocity and stress may be used in lieu of those shown on the typical sections.

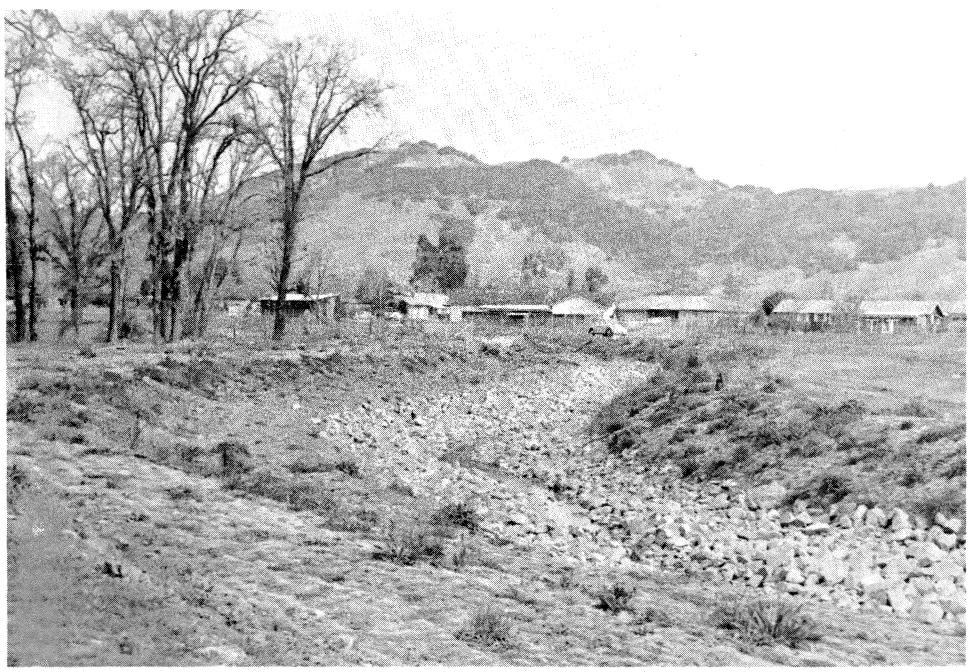


FIG. 6-4

EARTH CHANNEL
ROCK RIPRAP TO PROTECT STRESS AREAS

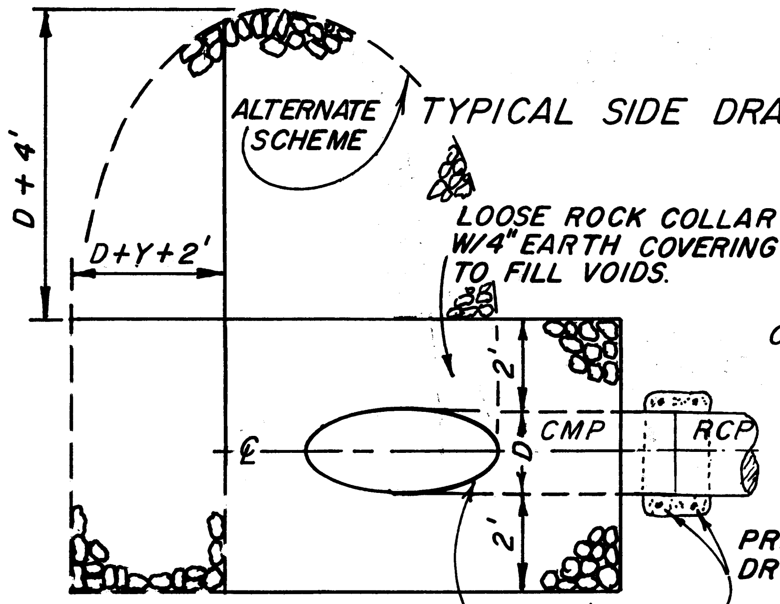
Bottom stabilization or protection may also be required where velocities are sufficient to cause invert erosion. Earth channels, in those areas not otherwise protected, shall be planted with an approved grass seed to establish a vegetative cover to the top of channel banks.

Drainage facilities shall be so constructed and areas adjacent to channels so graded that side drainage will enter in a manner which will prevent erosion within the rights-of-way. This will generally require constructed side inlets and collector ditches to carry side flow to the inlets. Typical side inlet structures are shown on Page 41.

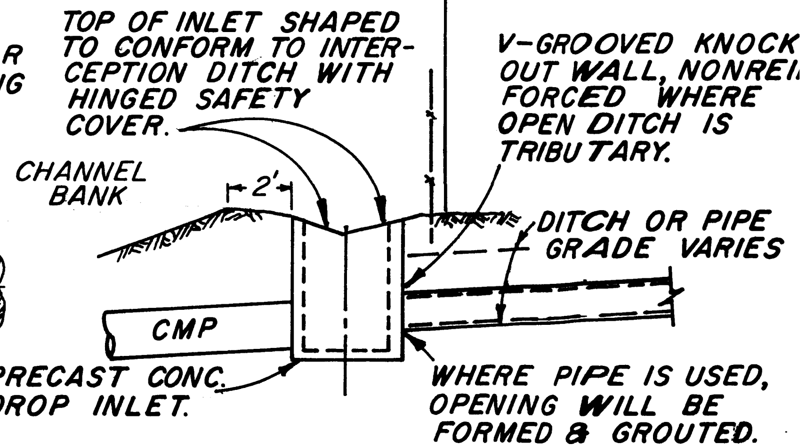
Alternate designs to these side inlet structures and rock collars, such as overspills, will be considered on the basis of the cross drain being maintenance-free, allowing no obstruction to maintenance equipment and being environmentally and aesthetically acceptable. The alternate may be rejected for aesthetic reasons alone.

Side inlets shall convey the flow under maintenance ways in culverts to the main channel inverts except where an acceptable alternate is approved. Galvanized metal conduit may be used for this purpose. Where closed conduits are not required for side drainage, other facilities such as lined valley gutters shall be provided to preclude occurrence of erosion within the waterway. Tributary waterways shall be conveyed under maintenance ways in closed conduit where such flows can be conveyed in 72-inch diameter or smaller galvanized metal conduit. Larger tributary waterways

TYPICAL SIDE DRAIN INSTALLATIONS

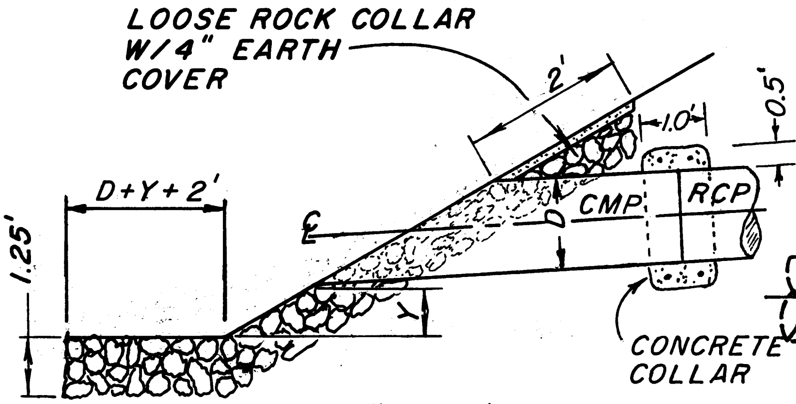


PLAN



ELEVATION

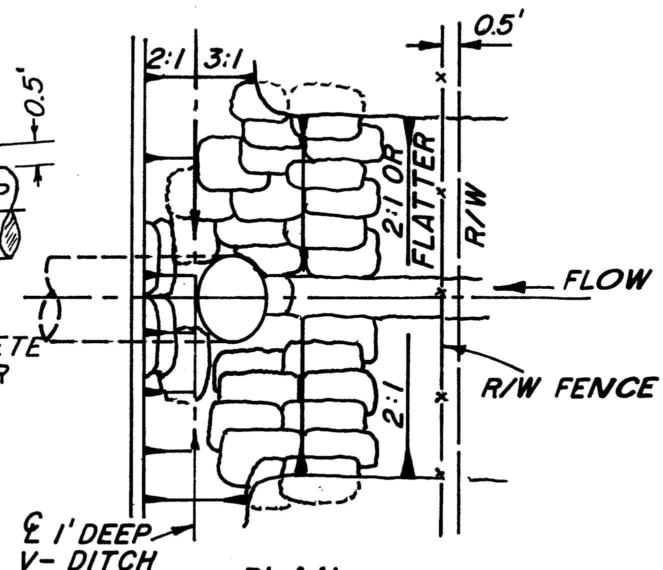
TYPICAL CMP INLET WITH CONCRETE DROP INLET



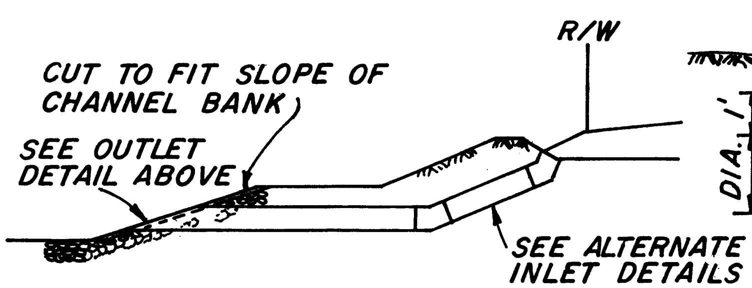
WHEN D < 24" Y = 2'
WHEN D ≥ 24" Y = 1'

ELEVATION

TYPICAL CMP OUTLET

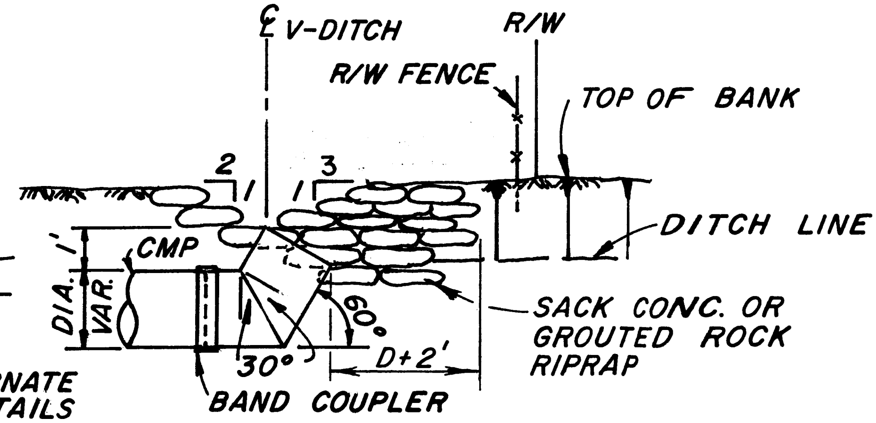


PLAN



ELEVATION

TYPICAL SIDE DRAIN INSTALLATION



ELEVATION

TYPICAL CMP INLET WITH SACK CONCRETE RIPRAP

REV. 6-83

may be placed in closed conduit for maintenance way crossings, or they may enter the main channel in properly designed open-channel junction structures. Major and secondary tributary waterways shall enter the main channel at an angle not exceeding 25 degrees from being parallel to flow in the main channel, and such junctions shall be designed in accordance with a momentum analysis of the flows. Where open channel tributaries cross maintenance ways, a convenient turn-around area shall be provided for maintenance vehicles. Minimum radius of a maintenance turn-around shall be 40 feet. Other acceptable configurations such as a hammerhead may be used.

Maintenance ways shall be rocked as shown on the drawings. The depressed maintenance way shall have a crushed rock surfacing 4-inches thick. The maintenance way along the bottom of the waterway shall have a crushed rock surfacing 6-inches thick. The rock shall be of sufficient quality to resist degradation under use by maintenance equipment and normal channel flows and shall have 1-1/2 inch maximum diameter and sufficient fines to produce a dense section when watered and compacted to at least 85 percent relative compaction based on California Test Method 216. The source and grading of material shall be approved by the Agency prior to placement on the service roads.

CHAPTER VII

STRUCTURAL DESIGN

Structural design and construction of drainage facilities shall be subject to the approval of the agency having maintenance jurisdiction. Structural design of all drainage facilities shall conform to accepted engineering practices and to the criteria set forth below.

Structures shall be designed and constructed such that hydraulic conditions in the upstream waterway will not be altered in a way which would cause degradation, erosion or other undesirable effects.

Insofar as is practicable, catch basins, manholes, inlet structures, etc., shall conform to standard plans of the agency having maintenance jurisdiction, but in any event shall be hydraulically acceptable.

Minimum dimension of conduit openings shall be 18-inches except that the minimum dimension may be 15-inches where entrance structures are provided which will prohibit debris accumulation in the conduit. Entrance structures shall be designed to allow passage of water with anticipated debris loading at entrance. The alignment of closed conduits shall be as nearly straight as practicable. Manholes or some other acceptable means of access shall be provided at or near all junctions, at all bends which are sharper than those formed by standard single bevel concrete pipe, and at intervals not to exceed 500 feet along the conduit.

Inverted siphons will not be permitted unless necessitated by unalterable existing conditions. Closed conduits, including non-reinforced and cast-in-place concrete pipe, shall be structurally designed to withstand earth and surcharge loads normally anticipated to be imposed thereon. Clearance between top of pipe and ground shall be sufficient to preclude displacement of or damage to the conduit by all loading and surface land uses. This will generally require a minimum of 2 feet of clearance. Conduits shall be designed to have a minimum useful life of 50 years. Normally, galvanized metal conduit will not be acceptable except for outlets into open waterways, unless extra protection is provided to prolong life. In the event of erosive conditions, extra wearing surface or coating will also be required in conduits.

Closed conduits outletting into open channels or waterways shall be galvanized corrugated metal pipe for approximately the last 20 feet immediately upstream from the outlet. Such pipes shall be beveled to fit flush with the channel bank, and shall be connected to non-metal conduit by means of a concrete collar reinforced with welded wire fabric.

CHAPTER VIII

RIGHT-OF-WAY REQUIREMENTS

A. GENERAL:

Land rights shall be provided in one of the following alternate forms:

1. Natural waterways, constructed channels and landscaped constructed waterways:

    a. Separate parcel easement dedicated on a subdivision map; adjacent lots shall not extend into the easement area.

    b. Fee simple, if purchased by the Agency.

    c. Fee simple or easement, if granted to Agency for no monetary consideration.

2. Closed conduits:

    a. Easement dedicated on a subdivision map as part of adjacent lots.

    b. Easement granted to Agency by purchase or for no monetary consideration.

Right-of-way requirements are shown on the drawings on pages 24, 25, 27, 28, 29, 30, 31 & 32, and are further described in Sections B, C and D below.

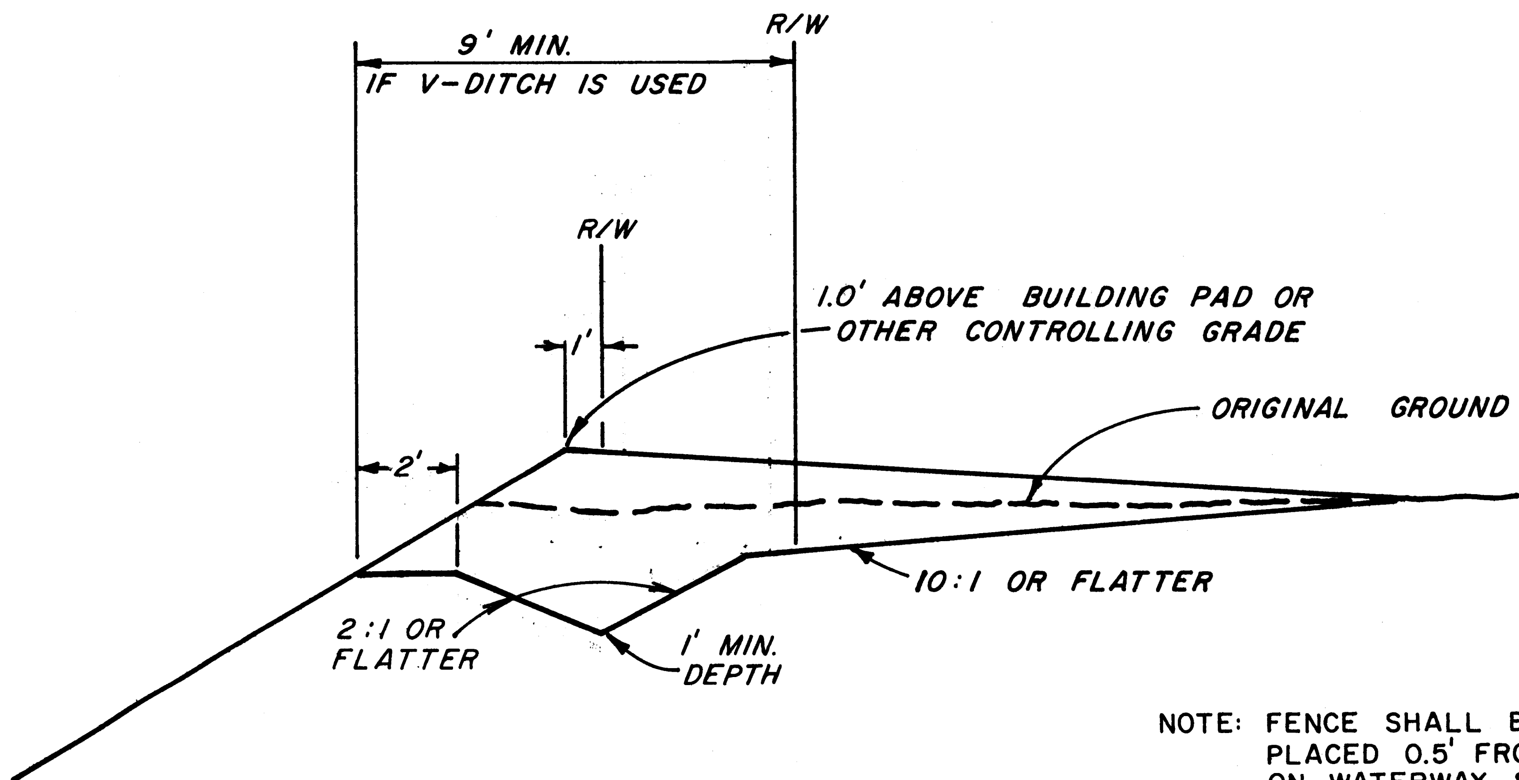
B. RIGHTS-OF-WAY FOR NATURAL WATERWAYS:

For natural waterways, a right-of-way shall be provided which includes the entire waterway area between the top of banks, together with a minimum 30 foot wide erosion buffer and access strip along the top of each bank. Top of bank is defined as that bank which is at or above the elevation of the adjacent natural ground outside of the waterway. A top of bank which is below another top of bank is a secondary top of bank. In the case of a natural waterway having earthen bank slopes steeper than 2-1/2 horizontal to 1 vertical, the right-of-way shall be increased to provide width for not less than 2-1/2 to 1 slopes from the existing toe of bank, plus the 30 foot wide erosion buffer and access strips. Toe of bank is defined as the bottom of the slope from the top of bank excluding secondary banks. Additional right-of-way will be required where unstable ground conditions exist.

Natural waterways as defined in these standards shall be delineated as described in Chapter II, Section B, of this manual.

C. <u>RIGHTS-OF-WAY FOR CONSTRUCTED CHANNELS, CONSTRUCTED NATURAL WATERWAYS AND LANDSCAPED CONSTRUCTED WATERWAYS AND APPURTENANCES</u>:

Constructed channels and landscaped constructed waterways with side slopes steeper than 6 to 1 shall have sufficient right-of-way provided to contain the top width of the channel plus a minimum of 20 feet for a continuous maintenance way and interception ditch on one side, and a minimum of 9 feet on the opposite side. An alternate to the 9 feet is shown on Page 47. The 20 foot maintenance way shall be provided on both sides of channels whose top width is greater than 50 feet. The right-of-way provided shall also include any cut slopes which may be required to allow for difference in elevation between the maintenance way and natural ground, except that if the adjacent natural ground is graded down to the maintenance way on a slope of 10 to 1 or flatter, the slopes need not be included within the right-of-way. In any case, cut slopes shall not be steeper than 3 to 1. Landscaped constructed



NOTE: FENCE SHALL BE PLACED 0.5' FROM R/W ON WATERWAY SIDE

ALTERNATE GRADING AT RIGHT OF WAY LINE

waterways with side slopes 6 to 1 or flatter shall have sufficient right-of-way provided to contain the top width of the waterway plus a minimum of 5 feet on each side.

Where ramps are not possible or access across is not allowed, such as the railroad and freeway, or where open channel tributaries are permitted to cross the maintenance way to enter the main channel, as described in Chapter V, additional right-of-way shall be provided to accommodate a minimum 40-foot radius turn-around for maintenance equipment or some other acceptable configuration.

At intersections of the channel with public roads, sufficient right-of-way shall be provided to permit access from the public road to the maintenance way. In the event that the right-of-way does not intersect a public road or projected public road, a turn-around or a 15-foot wide access right-of-way shall be provided from a public road to the channel right-of-way at intervals not to exceed one channel mile.

Right-of-way for lined channels shall extend to 0.5 foot outside the top of bank only, with a 15-foot wide access right-of-way provided to the channel from a public road at intervals along the channel of not more than 2,000 feet. Such access shall extend to channel invert by means of concrete access ramps having a maximum slope of 15 percent.

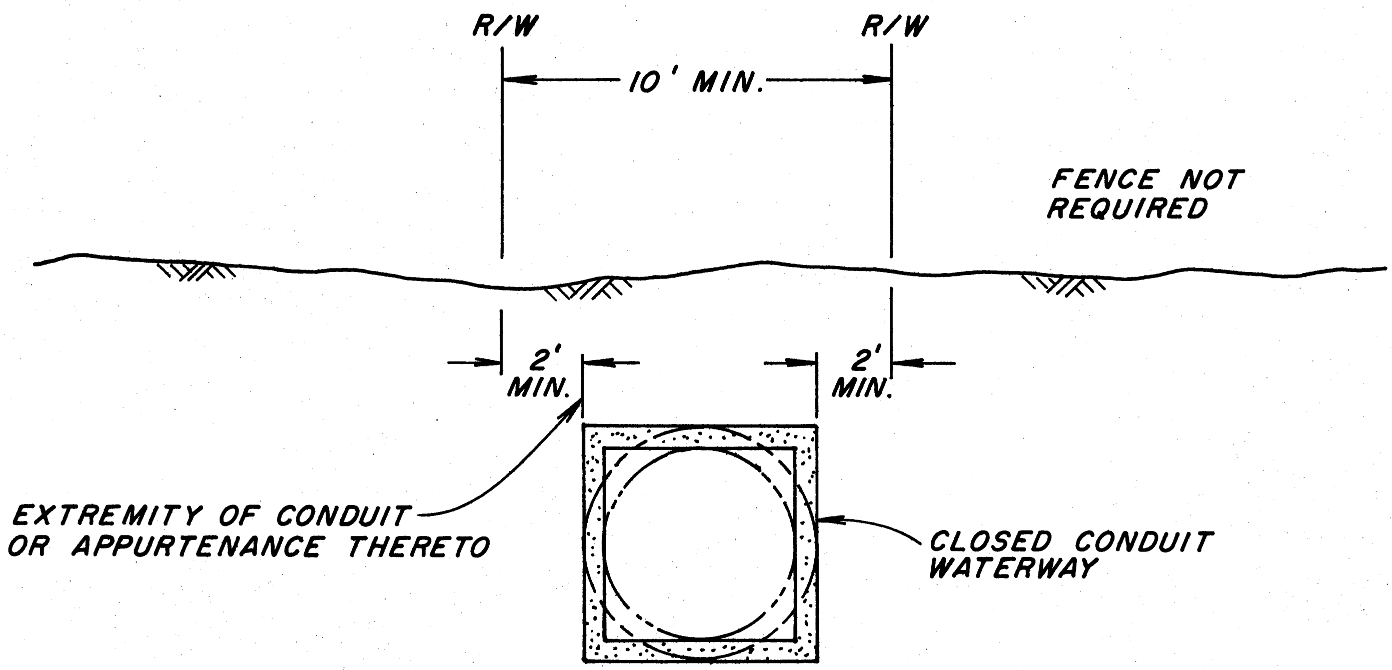
The right-of-way for landscaped constructed waterways may be the same as that designated for constructed channels or, at the option of the constructing individual or agency, right-of-way for such waterways may be increased as desired to provide additional area for planting or other landscaping. For such waterways whose side slopes are 6 to 1 or flatter, right-of-way shall equal or exceed that shown on Page 29.

Right-of-way for constructed natural waterways shall be established so as to meet the ultimate needs of such a waterway. These needs shall include ultimate roughness value, provision for erosion, natural reshaping and realignment, and access along the top of banks as shown on Page 28.

Where interim construction upstream or downstream of a project reach is required, in accordance with the provisions of Chapters I and V, all easements or rights-of-way, temporary or permanent, necessary for the performance of such work shall be acquired.

All constructed channels shall be fenced on both sides of the right-of-way as follows:

1. Within urban, suburban, and rural residential areas such fence shall be either 5 feet of chain link fabric with tension wire or 4 feet of chain link fabric and two strands of barbed wire for an overall fence height of 5 feet, or 4-foot high chain link with bar-top. Fourteen (14) foot long chain link drive gates shall be provided at all road intersections and at all other points of access to the maintenance way.
2. Within rural areas, field-type fence shall be provided consisting of 32 to 36-inch high sheeptight wire mesh with 3 strands of barbed wire for an overall fence height



RIGHT OF WAY FOR CLOSED CONDUITS

RIGHT OF WAY

of 54-inches. Fourteen (14) foot long drive gates shall be provided at all locations as specified above.

Landscaped constructed waterways shall be delineated in the same manner as natural waterways.

D. RIGHTS-OF-WAY FOR CLOSED CONDUITS AND APPURTENANCES:

A right-of-way sufficient to contain the closed conduit system and appurtenances plus a minimum of two feet on each side thereof shall be provided but in no event shall the right-of-way be less than 10 feet in width. Insofar as possible, rights-of-way for closed conduits shall be along or adjacent to property lines and outside of areas where structures are planned. No fencing is required for closed conduit rights-of-way.

Rights-of-way for interim work shall be provided as described in Section C above.

E. RIGHTS-OF-WAY AND ACCESS FOR RECREATIONAL USE:

Waterways lend themselves very well to providing necessary land and right-of-way for the pursuit of recreational activities, such as bicycling, hiking and horseback riding. These activities as well as others shall be considered as part of the usefulness of the waterway.

Bikeways may be required along waterways that are compatible with the general bikeway plan for the area. If a waterway falls into this category, the bike pathway shall have a riding surface suitable for general bike riding. Bike paths may be incorporated as part of the maintenance way provided the surfacing will withstand the loading of the maintenance vehicles. In general, the bike path surface width shall be at least 6 feet.

Hiking trails may also be part of the bike paths. However, horseback riding will not be allowed on the same path as the designated bike paths or hiking trails. The horse path shall be in a separate location, preferably on the opposite side of the channel.

REFERENCES

1. *Engineering Hydraulics*, Hunter House, John Wiley & Sons, 1950

2. *Engineering Design Standards, Far West States*, U. S. Department of Agriculture, Soil Conservation Service, 1958.

3. *Open-Channel Hydraulics*, Ven Te Chow, McGraw-Hill Book Company, 1959.

4. *Handbook of Channel Design for Soil and Water Conservation*, U.S. Department of Agriculture, Soil Conservation Service, Paper SCS-TP-61, 1947 (Stillwater Report).

5. *High Velocity Flow in Open-Channels*, Transactions ASCE, Vol. 116, 1951.

6. *Landscape Treatment for Flood Control Channels*, Sonoma County Planning Department, 1963.

7. *Standard Specifications for Public Works Construction*, latest edition, Northern California Chapter, American Public Works Association.

8. *Planning and Design of Open-Channels*, Technical Release No. 25, U. S. Department of Agriculture, Soil Conservation Service, (including Chapter 7).

9. *Open Channel Flow*, F. M. Henderson, Macmillan, 1969.

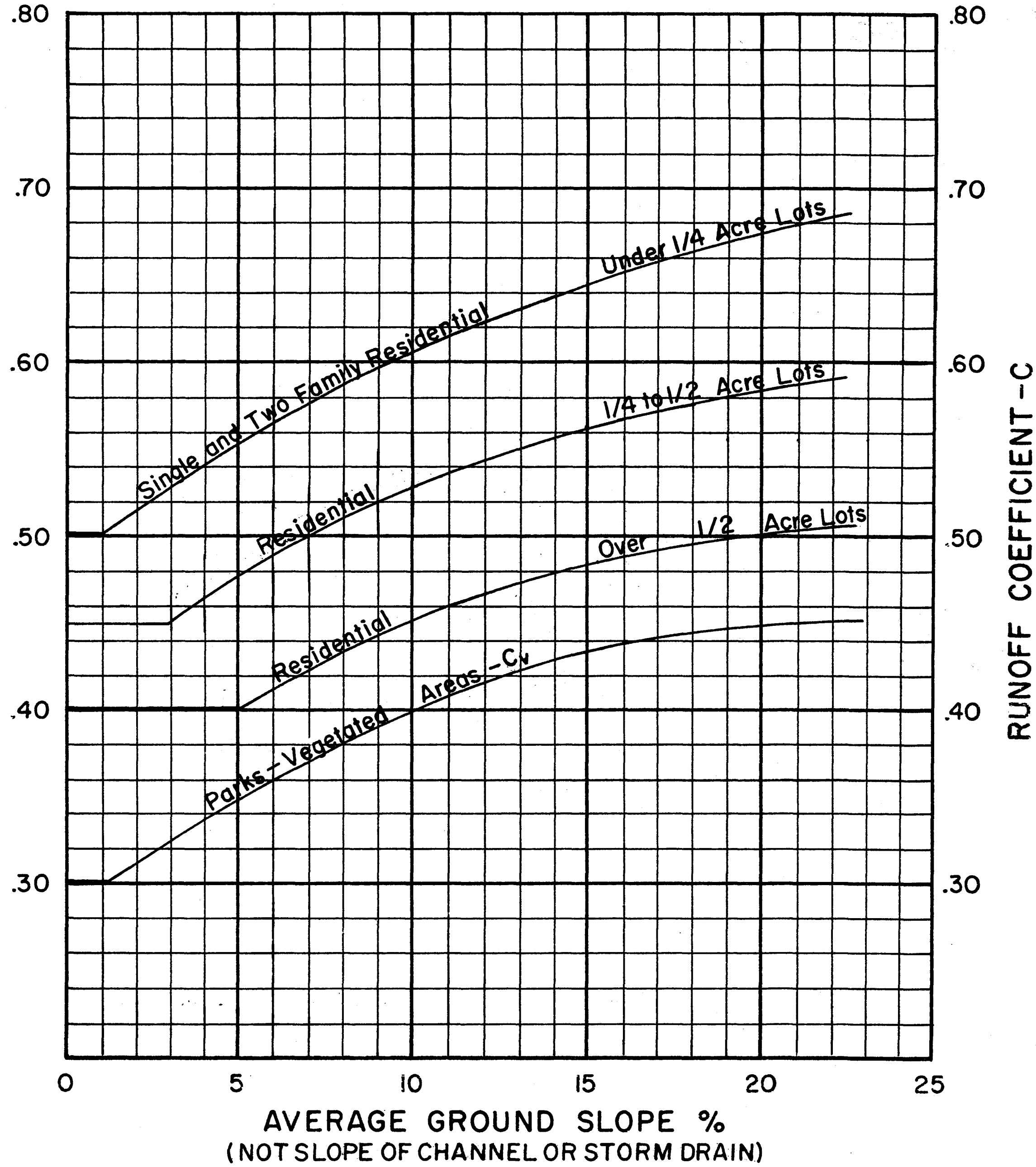
10. *Design Manual*, County of Los Angeles, Road Department

11. *Criteria Manual, Urban Storm Drainage*, Denver Regional Government.

12. *Roughness Characteristics of Natural Channels*, Harry H. Barnes, Jr., Geological Survey Water-Supply Paper 1849, U. S. Government Printing Office, Washington, 1967.

13. *Handbook of Applied Hydraulics,* C. V. Davis (Editor-in-Chief), McGraw-Hill Book Company, 1952.

RUNOFF COEFFICIENTS FOR RATIONAL FORMULA



NOTE: Commercial, Industrial & Multiple Residential Areas

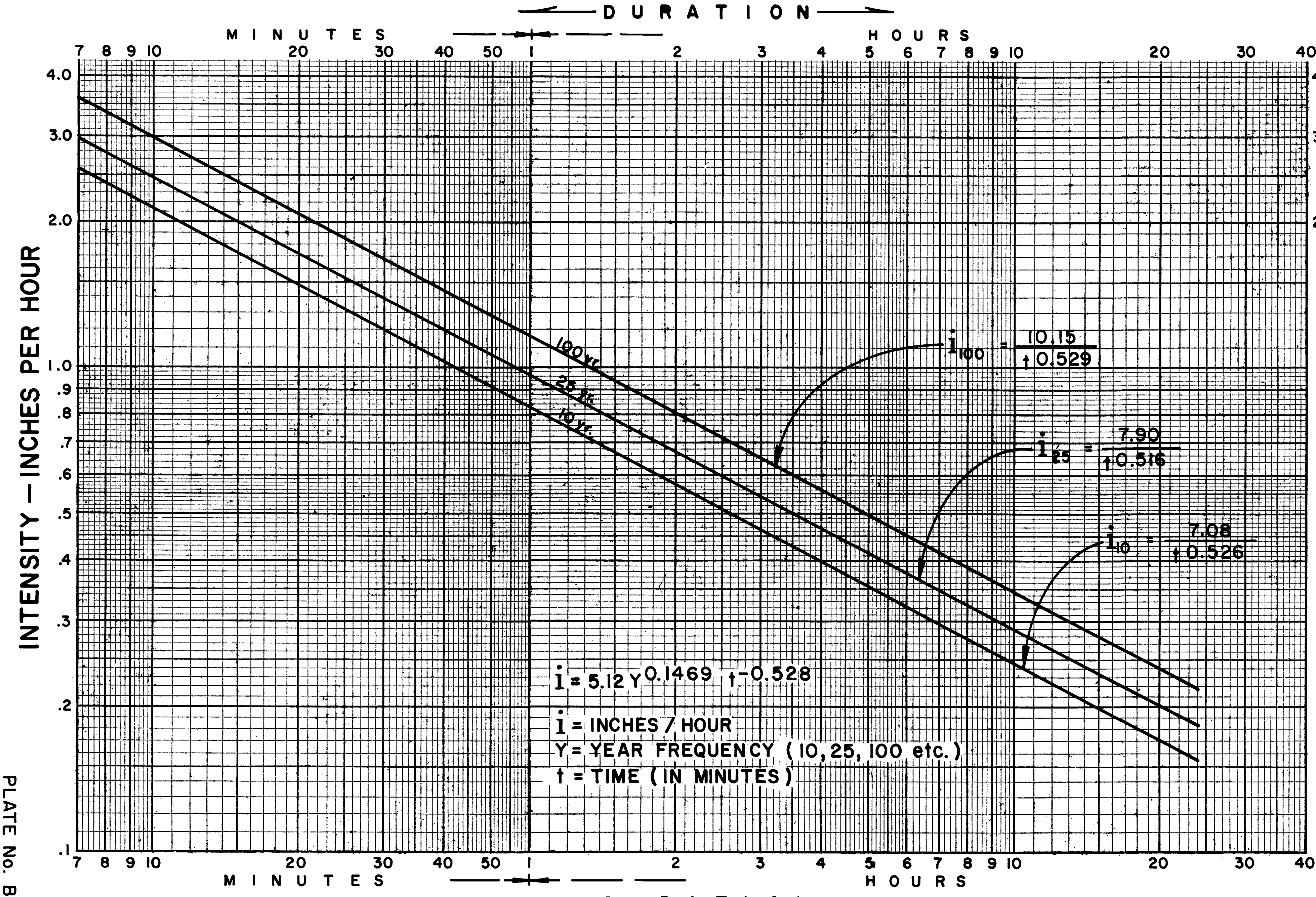
$C_P = 0.9$ (Based on paving, roofs, etc.)

When vegetated area exceeds 20% of total, C_V from vegetated curve may be used to reduce above C_P as follows:

$$C_T = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$$

SONOMA COUNTY WATER AGENCY

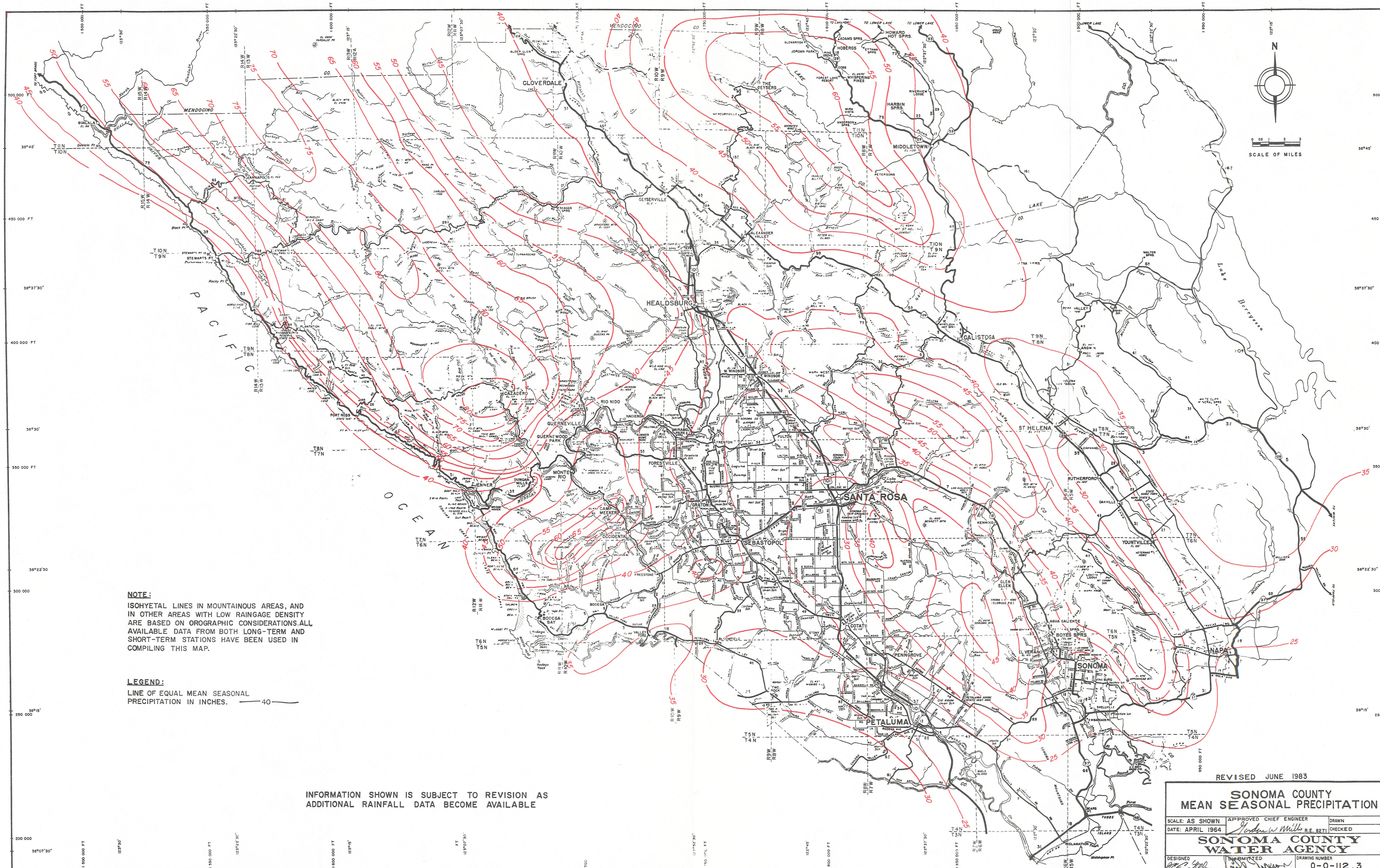
118-2
7/64



NOTE: THE INFORMATION SHOWN IS SUBJECT TO ANNUAL REVISION AS ADDITIONAL RAINFALL DATA BECOMES AVAILABLE.

RAINFALL
INTENSITY vs DURATION

insert



NOTE:

ISOHYETAL LINES IN MOUNTAINOUS AREAS, AND IN OTHER AREAS WITH LOW RAINGAGE DENSITY ARE BASED ON OROGRAPHIC CONSIDERATIONS. ALL AVAILABLE DATA FROM BOTH LONG-TERM AND SHORT-TERM STATIONS HAVE BEEN USED IN COMPILING THIS MAP.

LEGEND:

LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES. ——40——

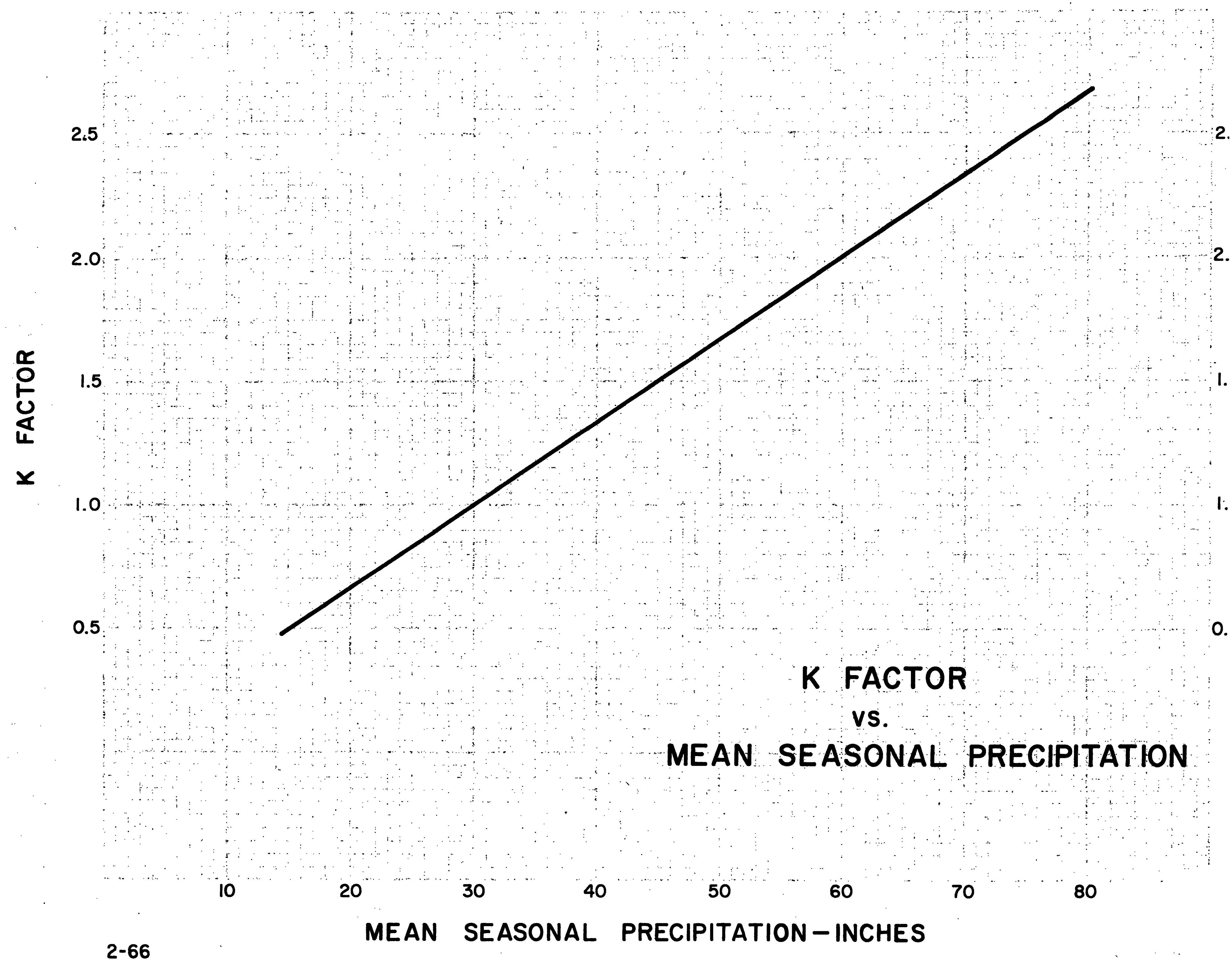
INFORMATION SHOWN IS SUBJECT TO REVISION AS ADDITIONAL RAINFALL DATA BECOME AVAILABLE

REVISED JUNE 1983

SONOMA COUNTY MEAN SEASONAL PRECIPITATION

SCALE: AS SHOWN	APPROVED CHIEF ENGINEER	DRAWN
DATE: APRIL 1964	R.E. 8271	CHECKED
SONOMA COUNTY WATER AGENCY		
DESIGNED	SUBMITTED	DRAWING NUMBER 0-0-112.3

PLATE No. B-3


K FACTOR
vs.
MEAN SEASONAL PRECIPITATION
K FACTOR
2.5
2.0
1.5
1.0
0.5
10
20
30
40
50
60
70
80
MEAN SEASONAL PRECIPITATION—INCHES

2-66

FORMULAS

SUPERELEVATION:

1. Rectangular channels

   a. Subcritical flow $S = \frac{3V^2 b}{4gR}$

   b. Supercritical flow $S = 1.2 \frac{V^2 b}{gR}$

2. Trapezoidal channels

   a. Subcritical flow $S = \frac{V^2(b+2Zd)}{2(gR-2ZV^2)}$

   b. Supercritical flow See Reference No. 5

INSTABILITY WAVES:

$$H_w = 0.25\, d_c \left[1 - 11.1 \left(\frac{S_o}{S_c} - 1\right)^2\right]$$

DEFINITIONS:

S = Superelevation above normal water surface (feet)

V = Average velocity (fps)

b = Channel bottom width (feet)

R = Centerline Radius (feet)

g = Acceleration due to gravity (fps^2)

Z = Co-tangent of bank slope

d = Normal depth (feet)

d_c = Critical depth (feet)

S_c = Critical slope

S_o = Channel bottom slope

H_w = Height of wave above normal depth (feet)

WATER AGENCY REVIEW OF DEVELOPMENT PLANS

PLAN CHECK GUIDELINES

This guideline on procedure and requirements was developed to make it possible for everyone to have the same opportunity for expeditious review by this office.

Procedure

1. Plans will normally be reviewed in the order in which they are received unless supporting data is missing or plan check fees are not received.

2. The plans will be returned to the engineer if they are incomplete or if there are no supporting calculations or the calculations are deficient or impossible to follow.

3. This office performs calculations only as needed to check the calculations of the developer's engineer.

4. This office will send a copy of all its correspondence concerning the plans to the County or City, and other interested entities, so that all parties may be fully informed as to the status of the plans.

5. This office will not review or give verbal or written approval of underground drainage systems until open channel facilities which are a part of the development improvements and which are designated for future maintenance by this Agency have been designed and found acceptable to this office.

Requirements

1. All drainage structures shall be designed in accordance with the Agency's Flood Control Design Criteria and close attention to the Criteria will facilitate early approval by this office.

2. Plan submittals shall have a letter of transmittal. The letter of transmittal shall include a general statement on the proposed improvements and provide detailed statements regarding any proposed deviations from Agency's Flood Control Design Criteria.

3. Two complete sets of plans shall be submitted for each plan check, if the developer's engineer wishes to have one set returned with revisions noted thereon.

4. The design aids and references which are used in support of the calculations for design of drainage improvements shall be listed. Be prepared to supply this office with copies of reference data if you have used something not in our reference file. If computers are used, the input and output shall be sufficient to allow easy checking.

5. Hydrologic and hydraulic calculations showing energy losses at junctions, bends, manholes, friction slopes, etc., shall be submitted by the engineer.

6. In addition to the calculations, the hydraulic gradeline and the energy gradeline shall be shown for all open or enclosed drainage improvements except gutters.

7. Plan views, profiles, cross-sections and details of all drainage facilities including a lot grading plan showing how each lot will drain shall be submitted.

8. The current fee for plan checking shall be submitted with the first submittal of plans in accordance with the fee schedule.

SAMPLE DRAINAGE COMPUTATIONS

An example of computing the quantities of storm water which can be anticipated to arrive at the boundaries of a proposed subdivision is herein presented. The method used is known as the Rational Formula as shown on Page 11.

1. Select the quadrangle sheet of the U. S. Geological Survey topographic map within which the proposed subdivision is located. In many cases, a larger scale topographic map may be necessary.
2. Impose the outlines of the proposed development on the map. Map must show on-site drainage and off-site drainage which affects the development. Map must show topography, drainage paths and areas used in the calculations.
3. On the map, draw in the outlines of the watersheds and lesser drainage basins along the ridge lines for all areas contributing storm water runoff to the development boundaries (Page E-1). In most instances, a field investigation must be made at this time to accurately determine the drainage basin outlines. This is particularly necessary if some portion of a contributing watershed has been developed. Also, during the field inspection, certain notes must be made of existing structures and unusual features within the watersheds and especially along the natural channels. The field inspection must include the areas adjacent to and downstream from the proposed development.

4. Overlay the proposed development boundaries, the watershed and drainage basin outlines, and the threads of the natural channels on the map with colored pencil (or some other acceptable means). (Page E-1)

5. Assign a letter designation to each watershed area and to sub-areas or small contributing drainage basins on the map. (Page E-1)

6. Designate by numerals those points at which the storm water flows are to be computed. Such points will include channel forks and junctions, points of entry into the proposed development, and any other "control" points which have been noted during the field inspection. (Page E-1)

7. Planimeter the areas on the map and list them in acres.

8. Use a computation sheet with columns and lines headed in a manner similar to Page E-2.

9. Select the uppermost watershed or sub-area and enter its point of concentration and its alphabetical designation as in Columns 1 and 2, Page E-2. Column 3 lists elevations from map.

10. Determine the runoff coefficient "C" for each sub-area based on the slope of the ground and the expected ultimate level of development using Page B-1. The intensity "i", Column 8 is based on the time of concentration, Columns 6 and 7 and Page B-2.

11. Enter the K-value determined from Pages B-3 and B-4.

12. Compute the average slope of the streamline for each

sub-area and enter the values in Column 4 on the computation sheet. Compute the average velocity between points of concentration using the slope of the streamline and the characteristic type of flow expected after ultimate development (i.e., natural mountain channel, gutter flow, reinforced concrete pipe, etc.) The average velocity is then used to compute the travel time which is entered on the computation sheet. Note that as the sub-areas are accumulative from the upper to the lower end of a watershed, so too are the time intervals and time of concentration.

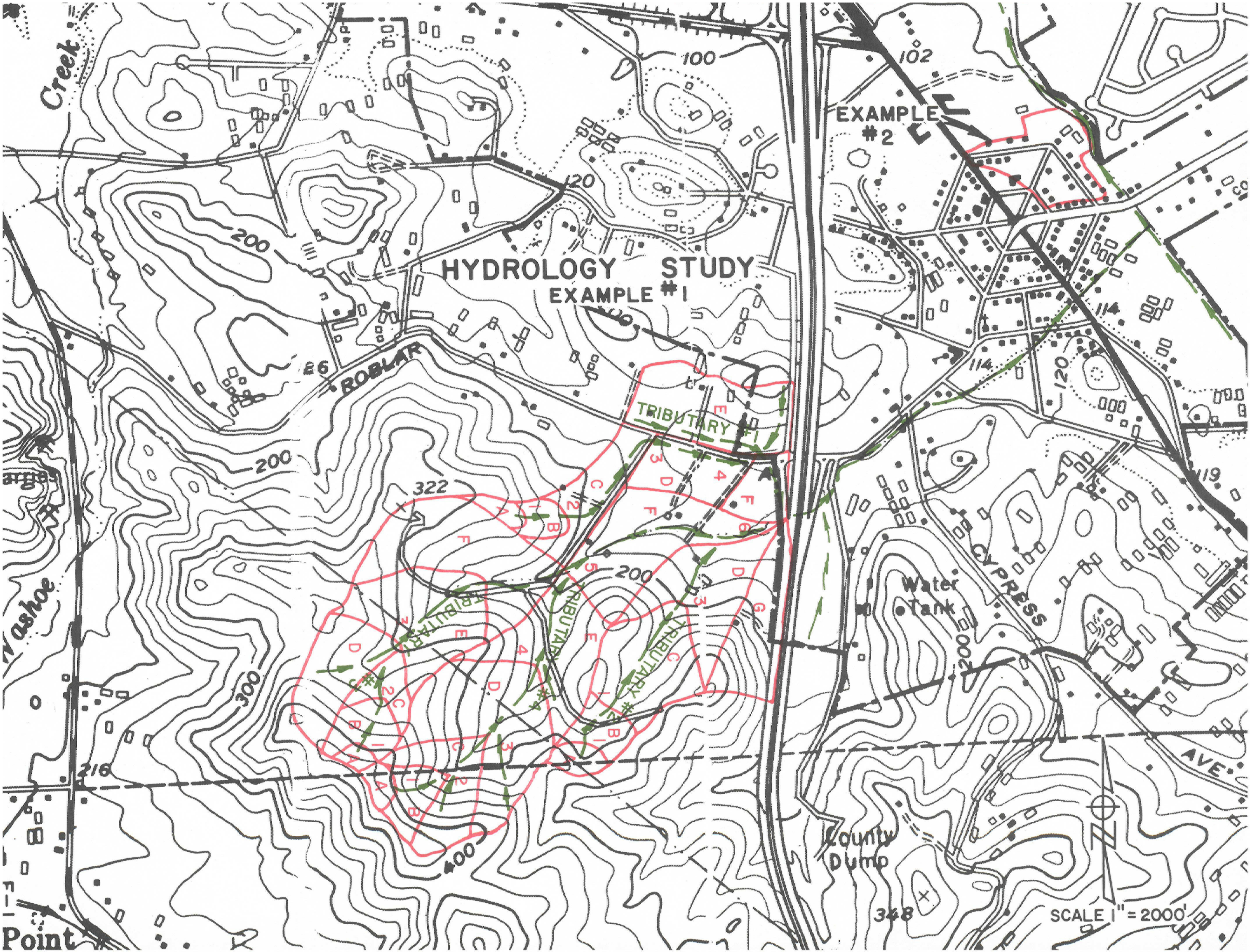
13. Compute the values of $K\Delta AC$ for each sub-area and enter the summation of these values in the column headed $\Sigma K\Delta AC$. This summation is a weighted value of the runoff from the several areas.

14. Using the time of concentration "t_c" as the shortest duration of rainfall for a design storm being of the required frequency (average recurrence interval) enter the frequency-duration-intensity chart (Page B-2) and find the rainfall intensity "i".

15. Compute the rate of storm water flow, $Q = \Sigma K\Delta AC$.

16. Complete the above computational process for each sub-area.

color copy
example 1


HYDROLOGY STUDY
EXAMPLE #1
EXAMPLE #2
TRIBUTARY #1
TRIBUTARY #2
TRIBUTARY #3
TRIBUTARY #4
ROBLAR
CYPRESS
AVE
Water Tank
County Dump
Creek
Washoe
Point
SCALE 1" = 2000'
N

RATIONAL METHOD DRAINAGE STUDY

By: M. L. Date 1-11-73 Subject Sample Hydrology-Cotati Area Example I Sheet No. 1 of 2

Chkd. By R. S. Date 1-23-73 Storm Freq. 10 % 10 yr. Less than one square mile drainage area Job. No.

Point of Conc.	Area	EL ft./ft. Distance	Slope ft./ft.	v ft./sec.	Time of Conc. (in minutes) Travel Time	Total Time	i in/hr.	K	C	ΔA acres / A Total	KΔAC	ΣKΔAC	Q ft³/sec.	Design	Remarks
					TRIBUTARY			1							
1	A	255 / 500			15 min.	initial	1.71	1.04	0.61	1.6 /	1.00		1.7	overland flow	
2	B	210 / 400	0.11	6	1.1	16.1	1.66	1.04	0.62	2.5 / 4.1	1.61	2.61	4.3	gutter	
3	C	165 / 1050	.043	11	1.6	17.7	1.59	1.04	0.60	10.4 / 14.5	6.50	9.11	14.5	15" RCP	
4	D+E	139 / 900	.029	10	1.5	19.2	1.50	1.04	0.54	9.8+20 / 44.3	16.7	25.8	38.8	18" RCP	(Area "D" Only)
6	F	135 / 650	.006	6	1.8	21.0	1.45	1.04	0.57	5.0 / 49.3	2.9	28.7	41.6	36" RCP	Enter Tributary 4
					TRIBUTARY			2							
1	A	290 / 300			15 min.	initial	1.71	1.04	0.63	1.8 /	1.18		2.0	overland flow	
2	B	265 / 500	.050	5	1.7	16.7	1.63	1.04	0.61	5.1 / 6.9	3.24	4.42	7.2	gutter flow	
3	C	200 / 1100	.059	14.4	1.3	18.0	1.56	1.04	0.50	16.3 / 23.2	8.48	12.90	20.2	18" RCP	
6	D	150 / 700	.071	17.5	0.7	18.7	1.53	1.04	0.56	14.4 / 37.6	8.38	21.3	32.6	24" RCP	Enter Tributary 4
					TRIBUTARY			3							
1	A	390 / 300			15 min.	initial	1.71	1.04	.50	1.4 /	0.73		1.24	overland flow	
2	B	335 / 350	0.16	7	0.8	15.8	1.68	1.04	.58	4.4 / 5.8	2.65	3.38	5.7	gutter flow	
3	C	290 / 500	0.09	15	0.6	16.4	1.64	1.04	.60	4.4 / 10.2	2.74	6.12	10.0	18" RCP	
3	D	290 / 0	Area D has shorter time than A, B, C. So 16.4 min. governs.			16.4	1.64	1.04	.57	11.8 / 22.0	7.01	13.1	21.5	18" RCP	

118-1 Rev. 7/64

RATIONAL METHOD DRAINAGE STUDY

By: M. L. Date 1-11-73 Subject Hydrology Example 1. Sheet No. 2 of 2

Chkd. By R. S. Date 1-23-73 Storm Freq. 10 % 10 yr. Job. No.

Point of Conc.	Area	EL / Distance	Slope	v	Time of Conc. (in minutes) Travel Time	Total Time	i	K	C	ΔA / A Total	KΔAC	ΣKΔAC	Q	Design	Remarks
4	E	220 / 1050	.067	17	1.0	17.4	1.59	1.04	.64	17.3 / 39.3	11.5	24.6	39.1	24"RCP	
5	F	190 / 650	.046	17.5	0.6	18.0	1.55	1.04	.61	25.6 / 64.9	16.2	40.8	63.4	30"RCP	Enter Tributary 4
					TRIBUTARY			4							
1	A	380 / 300			15 min.	initial	1.71	1.04	.63	1.5	0.98		1.68	overland flow	
2	B	315 / 400	0.16	7	1.0	16.0	1.66	1.04	.50	5.4 / 6.9	2.80	3.78	6.26	gutter flow	
3	C	268 / 550	.087	14	0.6	16.6	1.63	1.04	.58	11.1 / 18.0	6.71	10.5	17.1	18"RCP	
4	D	235 / 650	.051	16	0.7	17.3	1.59	1.04	.62	23.8 / 41.8	15.4	25.9	41.2	24"RCP	
5	E	190 / 900	.050	18	0.8	18.1	1.55	1.04	.63	18.6 / 60.4	12.2	38.1	59.1	30"RCP	Add Tributary 3
							1.55			64.9 / 125.3	40.8	78.9	122		Tributary 3
6	F	135 / 1950	.028	13.6	2.4	20.5	1.46	1.04	.55	24.2 / 149.5	13.8	92.7	135	42"RCP	Add Tributaries 1&2
						20.9	1.45			86.9 / 236.4	50.0	142.7	207		Tributary 1 Tributary 2
6	G	135 / 0	Area G has shorter time. So 20.9 min. governs.			20.9	1.45	1.04	.55	12.9 / 249.3	7.4	150.1	218	Enter Culvert	Existing

BY______ DATE______ SUBJECT Sample Hydrology SHEET NO. 1 OF______
CHKD. BY______ DATE______ Example 1 JOB NO.______

Supplementary Calculation For Hydrology

A. k-factor

Ave. annual rainfall = 31"/year

Ref. "Sonoma County mean seasonal precipitation" Plate No. B-3

k-factor = 1.04

Ref. "k-factor vs. mean seasonal precipitation" Plate No. B-4

B. C-Values

Ref. "Runoff coefficients for rational formula" Plate No. B-1

Tributary	Area	"Estimated" Average Ground Slope %	Ultimate Devlp.	C-Value
1	A	$\frac{40}{400} \times 100 = 10$ (The ave. slope between the 260 ft. and the 300 ft. contours)	Under 1/4 acre lots	.61
	B	$\frac{40}{330} = 12$ (The ave. slope between the 220 ft. and 260 ft. contours)	"	.62
	C	14 above 200 ft. contour (approx. 4* acres)	"	.64
		6 below 200 ft. contour (approx. 6.4* acres)	"	.57
		Ave. C-Value = .38*(.64)+.62*(.57)=.25+.35=.60		
	D	4	"	.54
	E	4	"	.54
	F	6	"	.57

$* \quad \frac{4}{6.4+4} = .38 \qquad \frac{6.4}{6.4+4} = .62$

Tributary	Area	"Estimated" Average Ground Slope %	Ultimate Devlp.	C-Value
2	A	13	Under 1/4 acre lots	0.63
	B	11	"	0.61
	C	20	Over 1/2 acre lots	0.50
	D	20 above 200 ft. contour (approx. 7.2 acres)	"	0.50
		11 below 200 ft. contour (approx. 7.2 acres)	Under 1/4 acre lots	0.61
		Ave. C-Value = 0.50(.50) + 0.50(.61) = .25 + .31 = 0.56		
4	A	13	Under 1/4 acre lots	0.63
	B	20	Over 1/2 acre lots	0.50
	C	19	1/4 to 1/2 acre lots	0.58
	D	12	Under 1/4 acre lots	0.62
	E	13	"	0.63
3	A	20	Over 1/2 acre lots	0.50
	B	18	1/4 to 1/2 acre lots	0.58
	C	9	Under 1/4 acre lots	0.60
	D	20 above 260 ft. contour (approx. 4 acres)	Over 1/2 acre lots	0.50
		10 below 260 ft. contour (approx. 7.8 acres)	Under 1/4 acre lots	0.60
		Ave. C-Value = .34(.50) + .66(.60) = .17 + .40 = 0.57		
	E	14	Under 1/4 acre lots	0.64
	F	11	"	0.61

Tributary	Area	"Estimated" Average Ground Slope %	Ultimate Devlp.	C-Value
4	F	20 above 200 ft. contour (approx. 7 acres)	Over ½ acre lots	0.50
		10 between 160 and 200 ft. contours (approx. 9 acres)	Under ¼ acre lots	0.61
		3 below 160 ft. contour (approx. 8.2 acres)		0.53
		Ave. C-Value = .29(.50)+.38(.61)+.33(.53) = .15+.23+.17 = 0.55		
	G	20 above 200 ft. contour (approx. 6.5 acres)	Over ½ acre lots	0.50
		10 below 200 ft. contour (approx. 6.4 acres)	Under ¼ acre lots	0.61
		Ave. C-Value = .50(50)+.50(.61) = .25+.30 = 0.55		

C. Time of Concentration

Tributary 1:

From point 1 to point 2

Q at point 1 = 1.7 c.f.s.

Estimated Q at point 2 $\cong$ 4.0 c.f.s.
(based on approx. 1 cfs/acre or slightly less)

Average Q in this reach is $1.7 + \frac{4.0-1.7}{2} = 2.9$ c.f.s.

Assume this flow is in a gutter, slope = 11%

∴ average velocity = 5.8 ft/sec.
Ref. City of Santa Rosa, Gutter Flow Chart

Travel time = 400 ft/(5.8 ft./sec.)(60 sec./min)
= 1.1 minutes

Tributary 1 - con'd

From point 2 to point 3

Q at point 2 = 4.3 c.f.s.
Estimated Q at point 3 ≅ 14 c.f.s.
Average Q between 2 and 3 = $4.3 + \frac{14-4.3}{2} =$ 8.2 c.f.s.

Assume a 15" pipe in this reach, slope = 4.3%, normal flow velocity assumed

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(8.2)(.014)}{(1.25^{8/3})(.043^{1/2})} = 0.31$$

From King's <u>Handbook of Hydraulics</u>, D/d = 0.60

$$\frac{A \text{ part-full}}{A \text{ full}} = 0.63$$

Ref. "Part-full Pipe Graph" Based on velocities or areas

A part-full = $0.63(1.23 \text{ ft}^2) = 0.77 \text{ ft}^2$

$$V = \frac{Q}{A} = \frac{8.2 \text{ ft}^3/\text{sec.}}{0.77 \text{ ft}^2} \cong 11 \text{ ft./sec.}$$

Travel time = 1050 ft./(11 ft./sec.)(60 sec/min.) = 1.6 min.

From point 3 to point 4

Q at point 3 = 14.5 c.f.s.
Estimated Q at point 4 = 20 c.f.s. (Area "E" not included)
Average Q between 3 and 4 = $14.5 + \frac{20-14.5}{2} =$ 17.3 c.f.s.

Assume 18" pipe flowing full at S = 2.9%

$$\therefore V = \frac{Q}{A} = \frac{17.3}{1.77} \cong 10 \text{ ft./sec.}$$

Travel time = 900 ft./(10 ft./sec.)(60 sec./min.) = 1.5 min.

Tributary 1 - con'd

From point 4 to point 6

Q at point 4 = 38.8 c.f.s.
This Q would determine the velocity of flow between points 4 and 6.

Assume a 36" R.C.P. flowing full at 0.6%
∴ Average velocity = Q/A = 39/7.07 = 6 ft./sec.
Travel time = 650 ft./(6 ft./sec.)(60 sec./min.) = 1.8 min.

Tributary 2

From point 1 to point 2

Q at point 1 = 2.0 c.f.s.
Estimated Q at point 2 = 7 c.f.s.
Average Q between 1 and 2 = $2 + \frac{7-2}{2} =$ 4.5 c.f.s.

Assume gutter flow at 5% slope
∴ Velocity = 5 ft./sec.
Ref. City of Santa Rosa, Gutter Flow Chart.

Travel time = 500 ft. /(5 ft./sec.)(60 sec./min.)
≅ 1.7 minutes

Tributary 2 - con'd

From point 2 to point 3

Q at point 2 = 7.2 c.f.s. ≅ 7
Estimated Q at point 3 ≅ 23 c.f.s.

Average Q between 2 & 3 = $9 + \frac{23-7}{2} = 17$ c.f.s.
Assume a 18" RCP at slope = 6% and normal flow

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(17)(.014)}{(1.5^{8/3})(.06^{1/2})} = .33$$

$D/d = 0.62$ Ref. "King's Handbook"
Full-flow velocity = 13.5 ft./sec.

$\frac{V\ part\text{-}full}{V\ full} = 1.07$ Ref. "Part-full Pipe Graph"

∴ Average velocity = (1.07)(13.5 ft/sec.) = 14.4 ft./sec.

Time of concentration = $\frac{1100\ ft.}{(14.4\ ft./sec.)(60\ sec/min.)} \cong 1.3$ min.

From point 3 to point 6

Q at point 3 = 20.2 c.f.s.
Estimated Q at point 6 ≅ 34 c.f.s.

Average Q between points 3 & 6 = $20 + \frac{34-20}{2} =$ 27 c.f.s.

Assume 24" RCP, slope = 7%, normal flow

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(27)(.014)}{(6.35)(.265)} = .225$$

$D/d = 0.49$ Ref. "King's Handbook"
Full-flow velocity = 17.7 ft./sec.

$\frac{V\ part\text{-}full}{V\ full} = 0.99$ Ref. "Part-full Pipe Chart"

∴ Average velocity = 17.5 ft./sec.

Tributary 2 - con'd

$$\text{Travel time} = \frac{700 \text{ ft.}}{(17.5 \text{ ft/sec})(60 \text{ sec/min.})} \cong 0.7 \text{ min.}$$

Tributary 3

From point 1 to point 2

Q at point 1 = 1.2 c.f.s.
Estimated Q at point 2 = 5.6 c.f.s.
Average Q between points 1 & 2 = $1.2 + \frac{5.6 - 1.2}{2} =$ 3.4 c.f.s.

Assume gutter flow at 12% slope
∴ Average velocity = 7 ft./sec.
Ref. City of Santa Rosa, Gutter Flow Chart

$$\text{Travel time} = \frac{350 \text{ ft.}}{(7 \text{ ft./sec.})(60 \text{ sec/min})} = 0.8 \text{ min.}$$

From point 2 to point 3

Q at point 2 = 5.7 c.f.s.
Estimated Q at point 3 = 10 c.f.s.
Average Q between points 2 & 3 = $5.7 + \frac{10 - 5.7}{2} =$ 7.9 c.f.s. say 8 c.f.s.

Assume 18" RCP at 9% slope

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(8)(.014)}{(2.95)(.30)} = 0.172$$

D/d = 0.42 Ref. "King's Handbook"

$$V \text{ full} = 16.6 \text{ ft./sec.}, \quad \frac{V \text{ part-full}}{V \text{ full}} = 0.92$$

$$\therefore \text{Average velocity} = 0.92(16.6 \text{ ft/sec.}) = 15 \text{ ft/sec.}$$

$$\text{Travel time} = \frac{500 \text{ ft.}}{(15)(60 \text{ sec./min.})} = 0.6 \text{ min.}$$

Tributary 3 - con'd

From point 3 to point 4

Q at point 3 = 21.5 c.f.s.
Estimated Q at point 4 = 38 c.f.s.
Average Q between points 3 & 4 = $22 + \frac{38-22}{2}$ = 30 c.f.s.
Assume 24" RCP at slope = 6.7%, normal flow

$$k' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(30)(.014)}{(6.35)(.259)} = 0.256$$

D/d = 0.53 Ref. "King's Handbook"

Full-flow velocity = 16.7 ft./sec. $\frac{V \text{ part-full}}{V \text{ full}} = 1.02$

∴ Average velocity = 1.02 (16.7 ft./sec.) = 17 ft./sec.

$$\text{Travel time} = \frac{1050 \text{ ft.}}{(17 \text{ ft./sec.})\, 60 \text{ sec./min.}} = 1.0 \text{ min.}$$

From point 4 to point 5

Q at point 4 = 39 c.f.s.
Estimated Q at point 5 = 60 c.f.s.
Average Q between points 4 & 5 = $39 + \frac{60-39}{2}$ = 50 c.f.s.
Assume 30" RCP, slope = 4.6%, normal flow

$$k' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(50)(.014)}{(11.5)(.215)} = 0.283$$

D/d = 0.57 Ref. "King's Handbook"

Full-flow velocity = 16.6 ft./sec. $\frac{V \text{ part-full}}{V \text{ full}} = 1.05$

∴ Average velocity = 1.05 (16.6 ft./sec.) = 17.5 ft./sec.

$$\text{Travel time} = \frac{650 \text{ ft.}}{(17.5)(60 \text{ sec./min.})} = 0.6 \text{ min.}$$

Tributary 4

From point 1 to point 2

Q at point 1 = 1.7 c.f.s.
Estimated Q at point 2 = 6.9 c.f.s.
Average between points 1 & 2 = $1.7 + \frac{6.9 - 1.7}{2} =$ 4.3 c.f.s.

Assume gutter flow at 12% slope
Average velocity = 7 ft./sec.
Ref. City of Santa Rosa, Gutter Flow Chart
Travel time = $\frac{400 \text{ ft.}}{(7 \text{ ft./sec.})(60 \text{ sec./min.})} = 1.0$ min.

From point 2 to point 3

Q at point 2 = 6.3 c.f.s.
Estimated Q at point 3 = 17 c.f.s.
Average Q between points 2 & 3 = $6 + \frac{17 - 6}{2} \cong$ 11 c.f.s.

Assume 18" RCP, slope = 8.7%, normal flow

$$K' = \frac{Qn}{d^{8/3}\, S^{1/2}} = \frac{(11)(.014)}{(2.95)(.295)} = 0.132$$

D/d = 0.37 Ref. "King's Handbook"
Full-flow velocity = 16.3 ft./sec.

$$\frac{V \text{ part-full}}{V \text{ full}} = 0.87$$ Ref. "Part-full Pipe Graph"

Average velocity = 0.87 (16.3 ft./sec.) = 14.2 ft./sec.
Travel time = $\frac{550 \text{ ft.}}{(14.2 \text{ ft./sec.})(60 \text{ sec./min.})} = 0.6$ min.

From point 3 to point 4

Q at point 3 = 17 c.f.s.
Estimated Q at point 4 = 40 c.f.s.

Tributary 4 - con'd

Average Q between points 3 & 4 $= 17 + \frac{40-17}{2} =$ 29 c.f.s.

Assume 24" RCP at slope = 5%, flowing normal

$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(29)(.014)}{(6.35)(.224)} = 0.286$

$D/d = 0.57$ Ref. "King's Handbook"

Full-flow velocity = 15 ft./sec. $\frac{V \text{ part-full}}{V \text{ full}} = 1.05$

Average velocity = 1.05(15 ft./sec.) = 15.8 ft./sec.

Travel time $= \frac{650 \text{ ft.}}{(15.8 \text{ ft./sec.})(60 \text{ sec./min.})} = 0.7$ min.

From point 4 to point 5

Q at point 4 = 41 c.f.s.

Estimated Q at point 5 = 59 c.f.s.

Average Q between points 4 & 5 $= 41 + \frac{59-41}{2} =$ 50 c.f.s.

Assume 30" RCP, slope = 5%, normal flow

$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{(50)(.014)}{(11.5)(.224)} = 0.272$

$D/d = 0.55$ Ref. "King's Handbook"

Full-flow velocity = 17.3 ft./sec. $\frac{V \text{ part-full}}{V \text{ full}} = 1.04$

Average velocity = 1.04 (17.3 ft./sec.) = 18 ft./sec.

Travel time $= \frac{900 \text{ ft.}}{(18 \text{ ft./sec.})(60 \text{ sec./min.})} = 0.8$ min.

Tributary 4 – con'd

From point 5 to point 6

Q at point 5 = 122 c.f.s.

Estimated Q at point 6 = 140 c.f.s.

Average Q between points 5 & 6 $= 122 + \frac{140-122}{2} =$ 131 c.f.s.

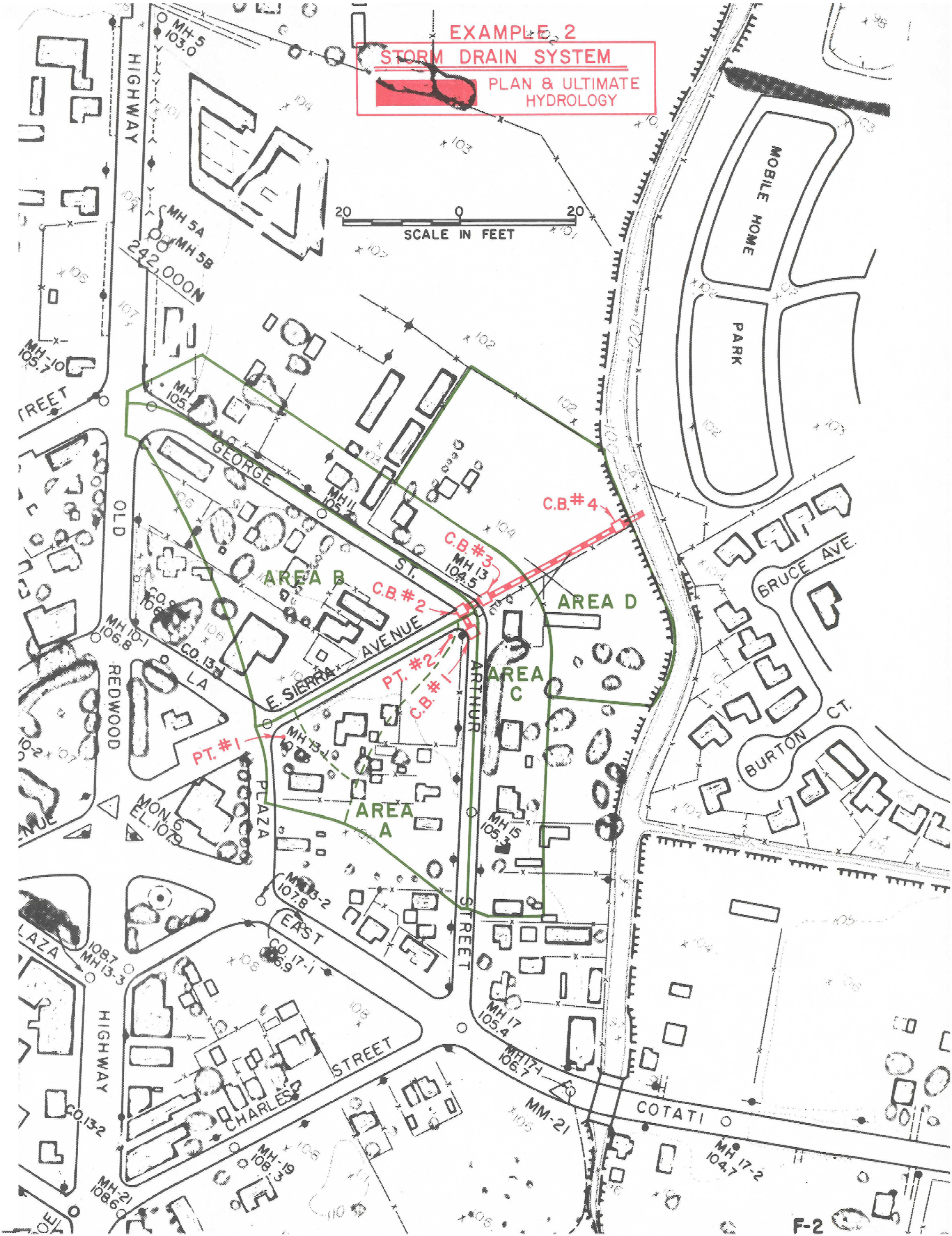
Assume 42" RCP flowing full

$$V = \frac{Q}{A} = \frac{131}{9.62} = 13.6 \text{ ft./sec.}$$

$$\text{Travel time} = \frac{1950 \text{ ft.}}{(13.6 \text{ ft./sec.})(60 \text{ sec./min.})} = 2.4 \text{ min.}$$

2 color copies existing drainage & storm drain


EXAMPLE 2
EXISTING DRAINAGE PATTERN
200 0 200
SCALE IN FEET
MOBILE HOME PARK
BRUCE AVE.
BURTON CT.
HIGHWAY
OLD REDWOOD HIGHWAY
GEORGE ST.
E. SIERRA AVENUE
LA PLAZA
ARTHUR STREET
EAST STREET
CHARLES STREET
COTATI
242,000N
MH-5 103.0
MH 5A
MH 5B
MH-10 105.7
MH 105.1
MH 11 105.3
MH 13 104.5
MH 10-1 106.8
CO. 13
MH 13-1
MON 6 EL. 107.9
MH 15 105.3
MH 13-2 107.8
CO. 17-1 106.9
108.7 MH 13-3
MH 17 105.4
MM-21
MH-19 106.3
MH-21 108.6
CO. 13-2
MH 17-2 104.7
F-1


EXAMPLE 2
STORM DRAIN SYSTEM
PLAN & ULTIMATE
HYDROLOGY
20 0 20
SCALE IN FEET
AREA A
AREA B
AREA C
AREA D
PT. #1
PT. #2
C.B. #1
C.B. #2
C.B. #3
C.B. #4
MH 13
104.5
GEORGE ST.
E. SIERRA AVENUE
ARTHUR STREET
OLD REDWOOD HIGHWAY
EAST STREET
CHARLES STREET
COTATI
BRUCE AVE.
BURTON CT.
MOBILE HOME PARK
PLAZA
MON. 6
EL. 107.9
242,000N
MM-21

Note: Ultimate development of this area is commercial and mult-residential.

RATIONAL METHOD DRAINAGE STUDY

By: M. L. Date 1-11-73 Subject Hydrology Example 2 Sheet No. 1 of 1

Chkd. By R. S. Date 1-23-73 Storm Freq. 10 % 10 yr. Total drainage area is less than one sq. mile. Job. No.

Point of Conc.	Area	EL ft. / ft. Distance	Slope ft./ft.	v ft./sec.	Time of Conc. (in minutes) Travel Time	Total Time	i in/hr.	average rainfall 29"/yr. K	C	ΔA acres / A Total	KΔAC	ΣKΔAC	Q ft.³/sec.	Design	Remarks
Point 1	A	107.3 /			10 min.	10 min.	2.10	0.97	0.90	.51 / .51	.45	.45	.93	runoff to street	
Point 2	A	104.7 / 390	.0067	approx 2.0	3.2	13.2	1.84	0.97	0.90	.80 / 1.31	.70	1.15	2.10	gutter flow	E. Sierra Avenue
CB#1	A					13.2	1.84	0.97	0.90	1.48 / 2.79	1.29	2.44	4.5		Enter CB#1
CB#2	B	/ 40		3.6	0.2	13.4	1.82	0.97	0.90	3.05 / 5.84	2.66	5.10	9.3	Assume 15" RCP	$V=\frac{Q}{A}=\frac{4.5}{1.23}=3.6$
CB#3	C	/ 40		5.2	0.1	13.5	1.81	0.97	0.90	3.35 / 9.19	2.92	8.02	14.5	Assume 18" RCP	$V=\frac{9.3}{1.78}=5.2$ ft./sec.
CB#4	D	/ 300		4.6	1.1	14.6	1.75	0.97	0.90	3.09 / 12.28	2.70	10.72	18.8	Assume 24" RCP	$V=\frac{14.5}{3.14}=4.6$ ft./sec.
														Assume 24" CMP	

COMPUTATION FORM FOR UNDERGROUND PIPE DRAINAGE SYSTEMS

CATEGORY	PIPE DATA			FLOW DATA					HEAD LOSSES					ELEVATIONS			
ITEM	LENGTH	DIAMETER	AREA	MANNINGS COEFF.	FLOW	VELOCITY	VELOCITY HEAD	FRICTION SLOPE	FRICTION LOSS	CONTRACTION LOSS	ENLARGEMENT LOSS	BENDS & OTHER LOSSES	SUMMATION OF LOSSES	ENERGY GRADE	HYDRAULIC GRADE	INLET GRADE	INVERT GRADE
SYMBOL	L	D	A	n	Q	V	$V^2/2g$	$S_f = 4.66 \frac{n^2 Q^2}{d^{5.33}}$	$H_f = S_f L$	H_C	H_E	H_B	ΣH	E.G.L.	H.G.L.	F.G.	INV.
UNIT / ELEMENT	Ft	Ft	Ft^2		$Ft^3/sec.$	$Ft/sec.$	Ft	Ft/Ft	Ft	Ft	Ft	Ft	Ft	ELEV. IN FT.	ELEV. IN FT.	ELEV. IN FT.	ELEV. IN FT.
Laguna															100.90		93.5
Outlet		2.5	4.91		18.8	3.83	0.23				(1) 0.23		0.23	101.13	100.90		93.5
30" CMP	30	2.5	4.91	0.024	18.8	3.83	0.23	0.00716	(6) 0.22				0.22				
Inlet		2.5	4.91		18.8	3.83	0.23			(2) 0.03			0.03	101.35	101.12		98.5
C.B. #4					18.8 / 14.5									101.38		103.0	
Outlet		2.5	4.91		14.5	2.95	0.14				(3) 0.04		0.04	101.42	101.28		98.6
30" RCP	300	2.5	4.91	0.014	14.5	2.95	0.14	0.00145	(6) 0.43				0.43				
Inlet		2.5	4.91		14.5	2.95	0.14			(2) 0.02			0.02	101.85	101.71		99.2
C.B. #3					14.5 / 9.3									101.87		103.6	
Outlet		1.75	2.41		9.3	3.86	0.23				(3) 0.06		0.06	101.93	101.70		99.6
21" RCP	40	1.75	2.41	0.014	9.3	3.86	0.23	0.00399	(6) 0.16				0.16				
Inlet		1.75	2.41		9.3	3.86	0.23			(2) 0.04			0.04	102.09	101.86		99.8
C.B. #2					9.3 / 4.5							(4) 0.35	0.35	102.48		103.7	
Outlet		1.25	1.23		4.5	3.66	0.21				(3) 0.06		0.06	102.54	102.33		100.3
15" RCP	40	1.25	1.23	0.014	4.5	3.66	0.21	0.00563	(6) 0.23				0.23				
Inlet		1.25	1.23		4.5	3.66	(5) 0.21			(2) 0.03			0.03	102.77	102.56		100.5
C.B. #1					4.5									102.80	102.80	103.8	

TYPICAL HEAD LOSS VALUES. USE OTHER VALUES WHERE APPROPRIATE.

(1) HEAD LOSS AT OUTLET – $1.0\ V^2/2g$

(2) HEAD LOSS AT CONTRACTION – $0.15\ V^2/2g$

(3) HEAD LOSS AT ENLARGEMENT – $0.25\ V^2/2g$

(4) HEAD LOSS AT 90° TURN – $1.5\ V^2/2g$

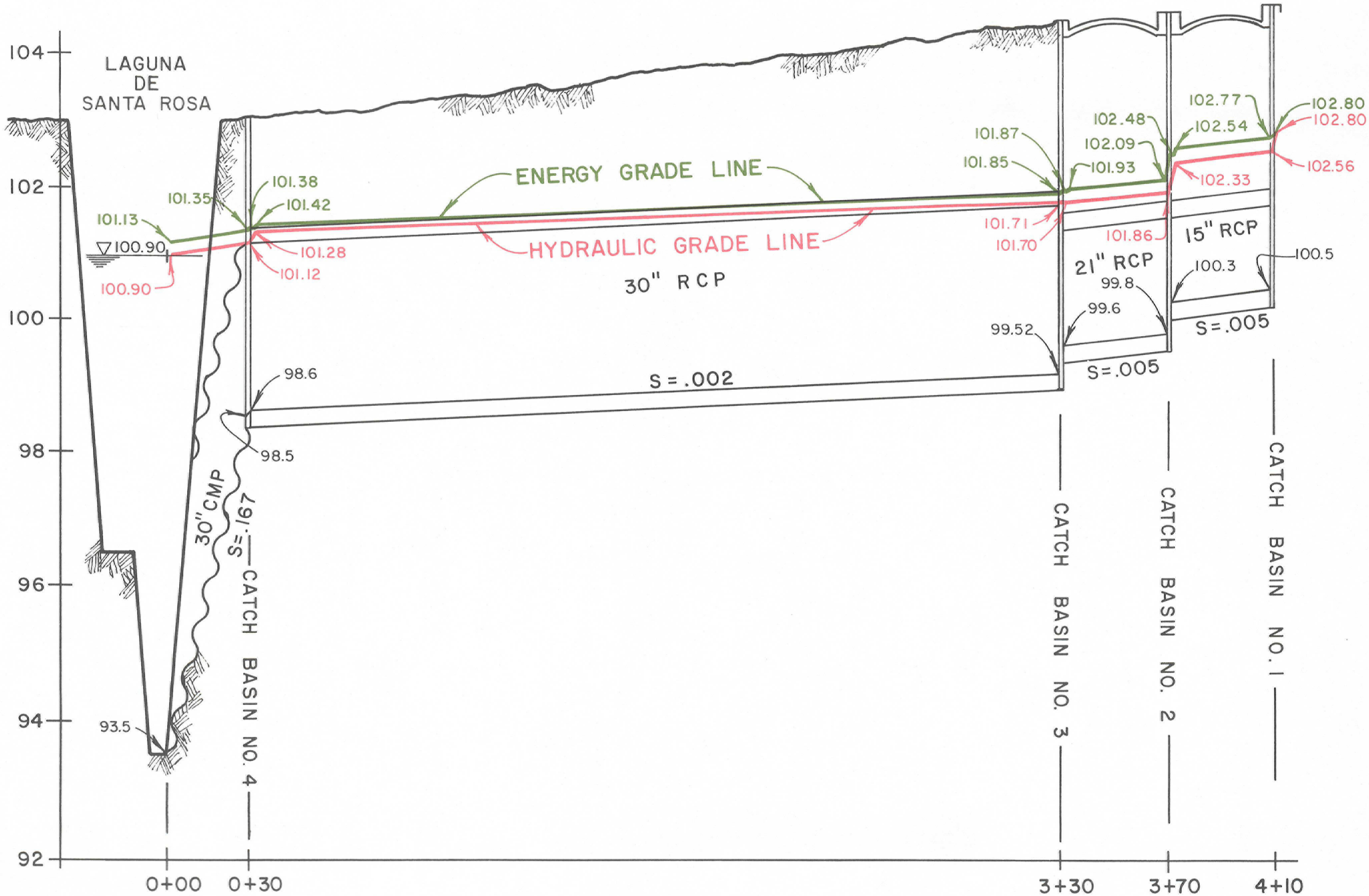
(5) CONVERSION AT ENTRANCE – $1.0\ V^2/2g$

(6) HEAD LOSS BY PIPE FLOW – $S_f \times L$

CALC. BY________ DATE ________ PROJECT EXAMPLE 2 SHEET NO. 1 OF 1

CHKD. BY________ DATE ________ ________ JOB NO. ________

color
example 2

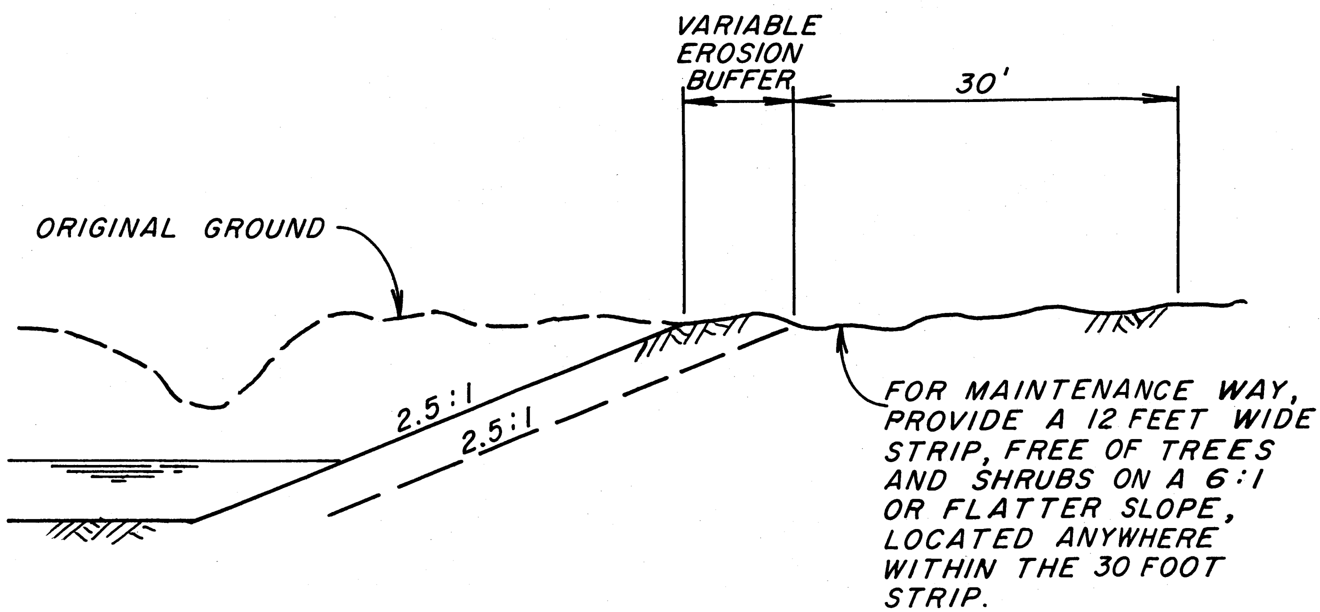


LAGUNA DE SANTA ROSA
ENERGY GRADE LINE
HYDRAULIC GRADE LINE
30" RCP
21" RCP
15" RCP
30"CMP
S=.167
S=.002
S=.005
S=.005
CATCH BASIN NO. 4
CATCH BASIN NO. 3
CATCH BASIN NO. 2
CATCH BASIN NO. 1
101.13
101.35
101.38
101.42
100.90
100.90
101.28
101.12
98.6
98.5
93.5
101.87
101.85
101.71
101.70
99.52
102.48
102.09
101.93
101.86
99.8
99.6
102.77
102.54
102.33
100.3
102.80
102.80
102.56
100.5
104
102
100
98
96
94
92
0+00
0+30
3+30
3+70
4+10

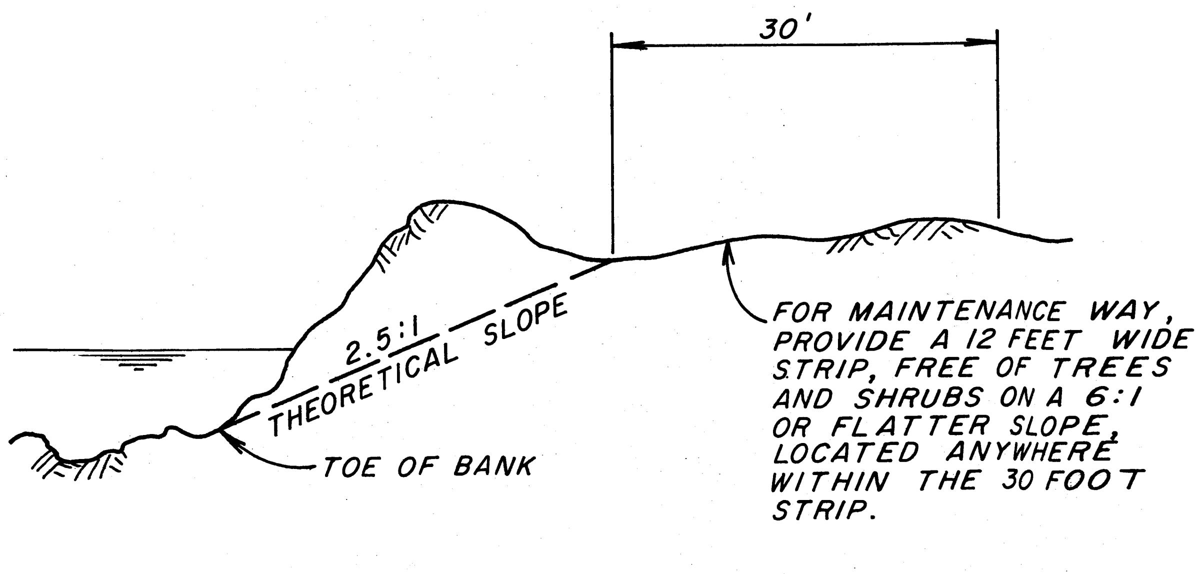
EXAMPLE 2

SUMMARY OF DESIGN ALTERNATES

SIDE SLOPE, MAINTENANCE ROAD & CHANNEL BOTTOM ALTERNATES

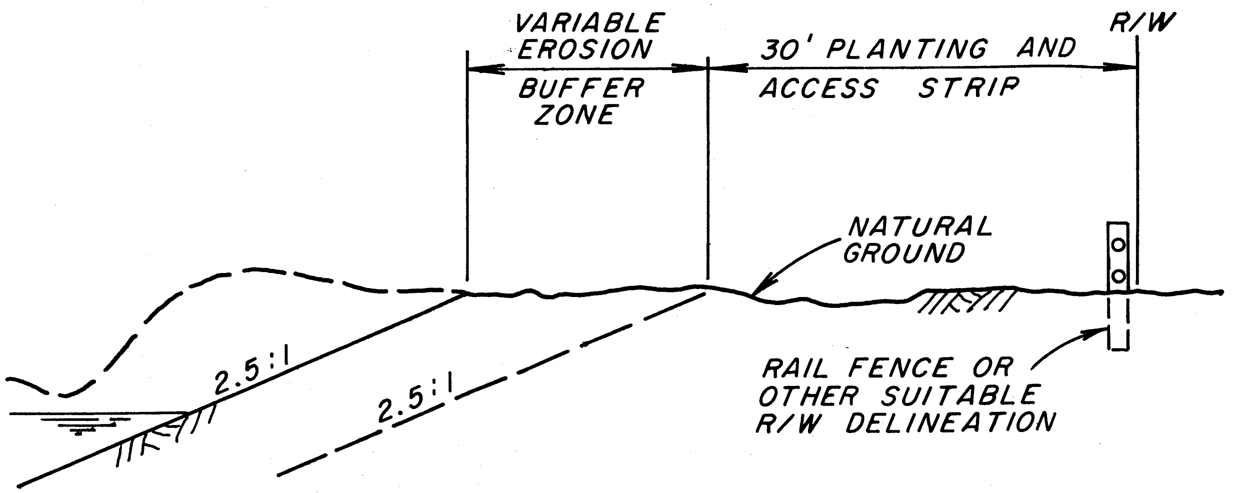


CONSTRUCTED NATURAL WATERWAY
WHERE VELOCITY IS LESS THAN 6 ft./sec.

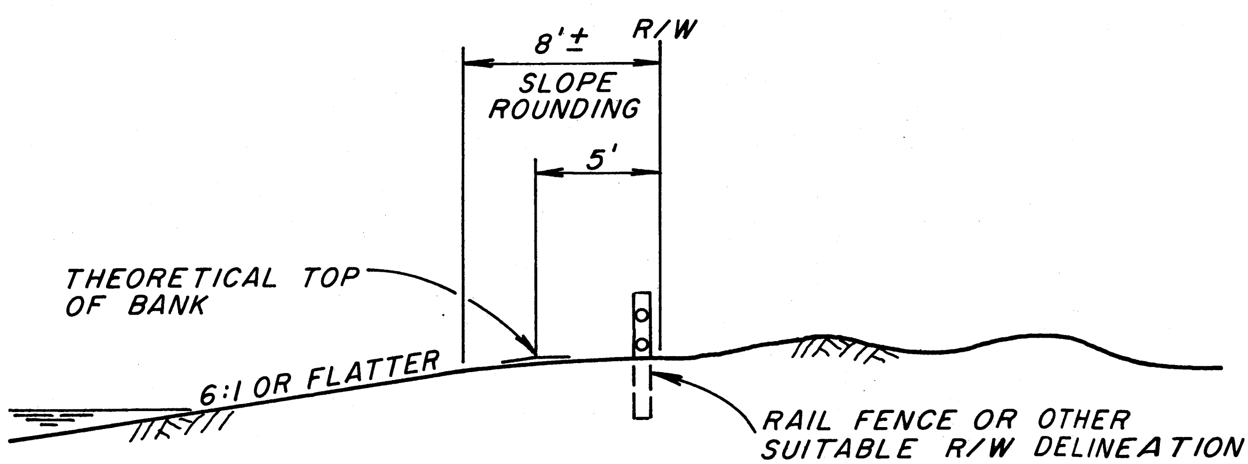


NATURAL CREEK

TOP OF BANK, R/W & FENCING ALTERNATES

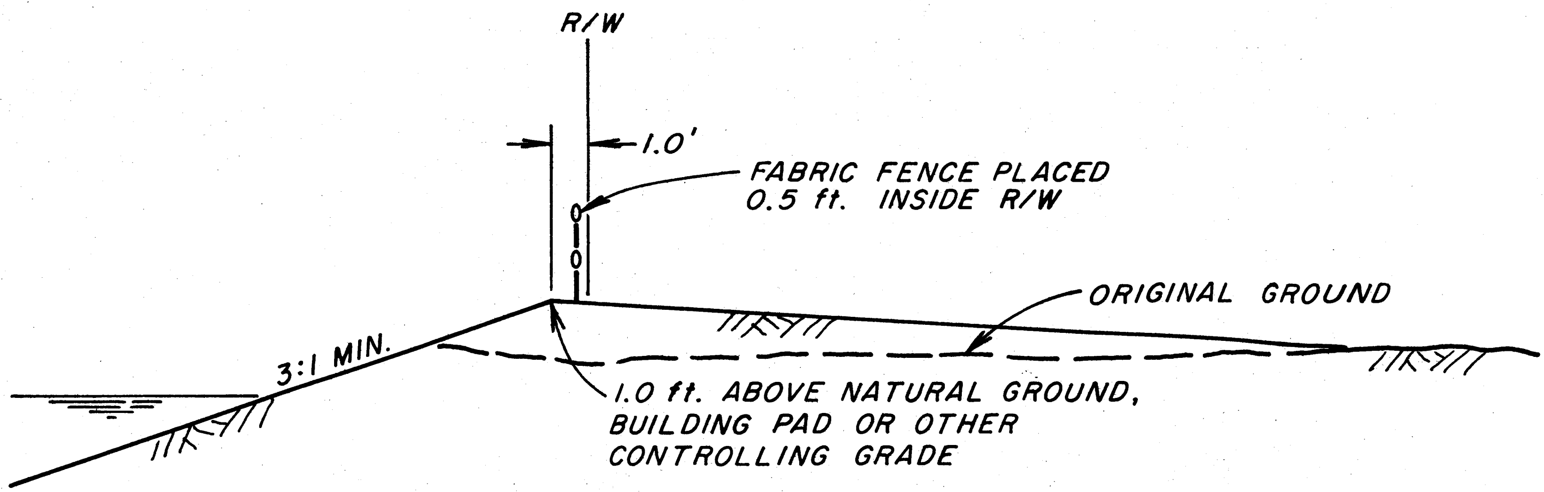


CONSTRUCTED NATURAL WATERWAY

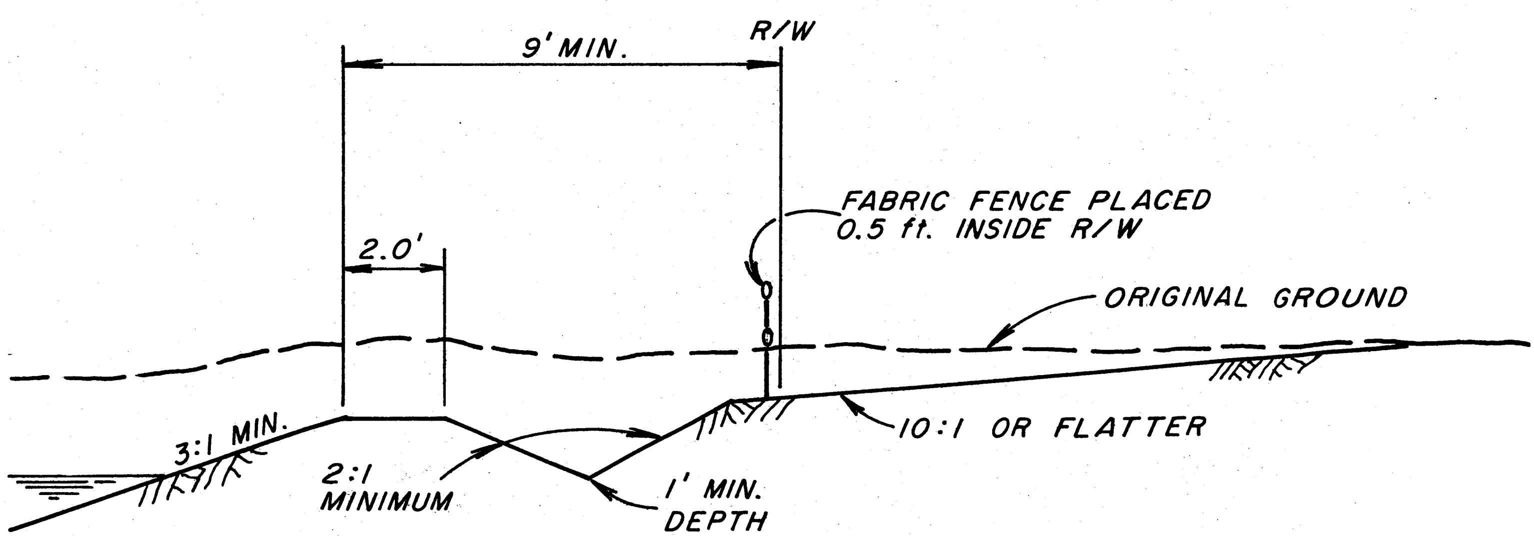


FLAT SIDE SLOPES

TOP OF BANK, R/W & FENCING ALTERNATES

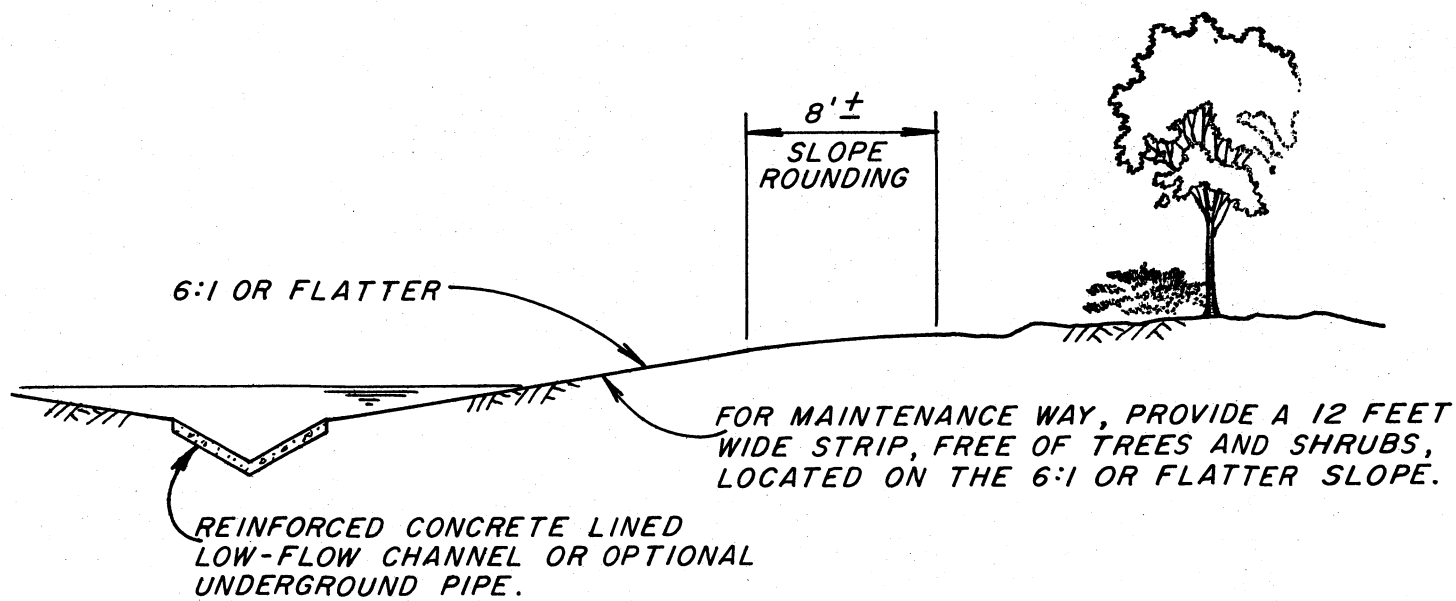


IF NO RUNOFF PASSES INTO THE CREEK
RIGHT OF WAY

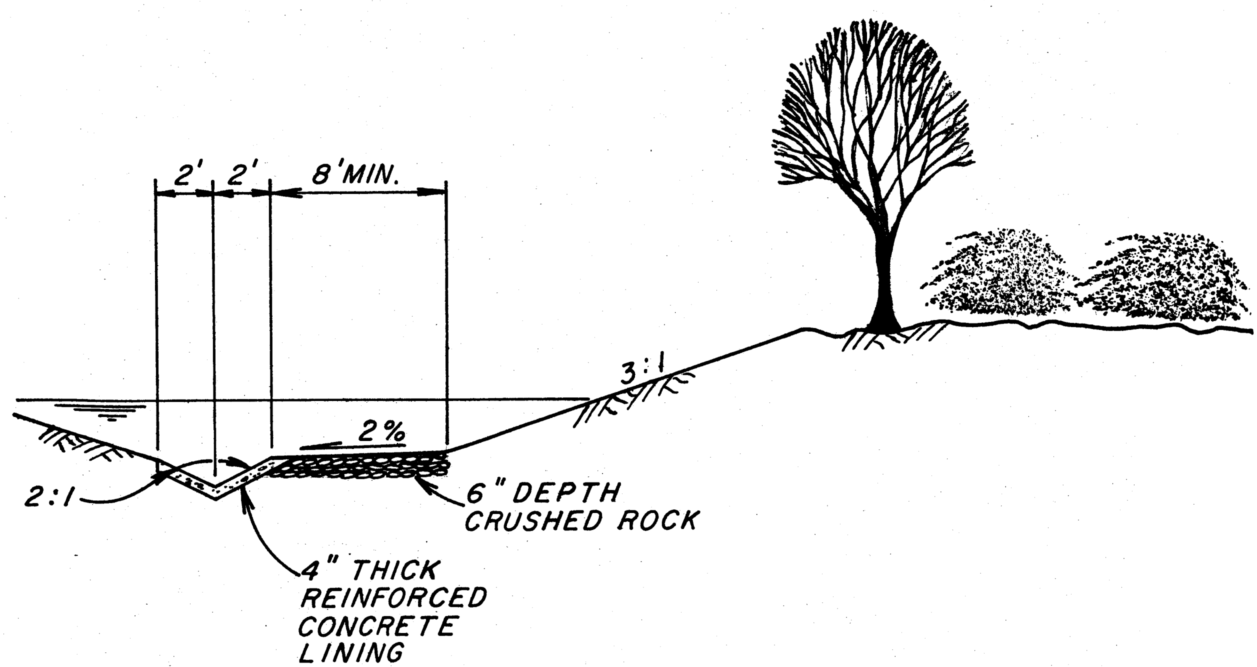


STANDARD CHANNEL

SIDE SLOPE, MAINTENANCE ROAD & CHANNEL BOTTOM ALTERNATES

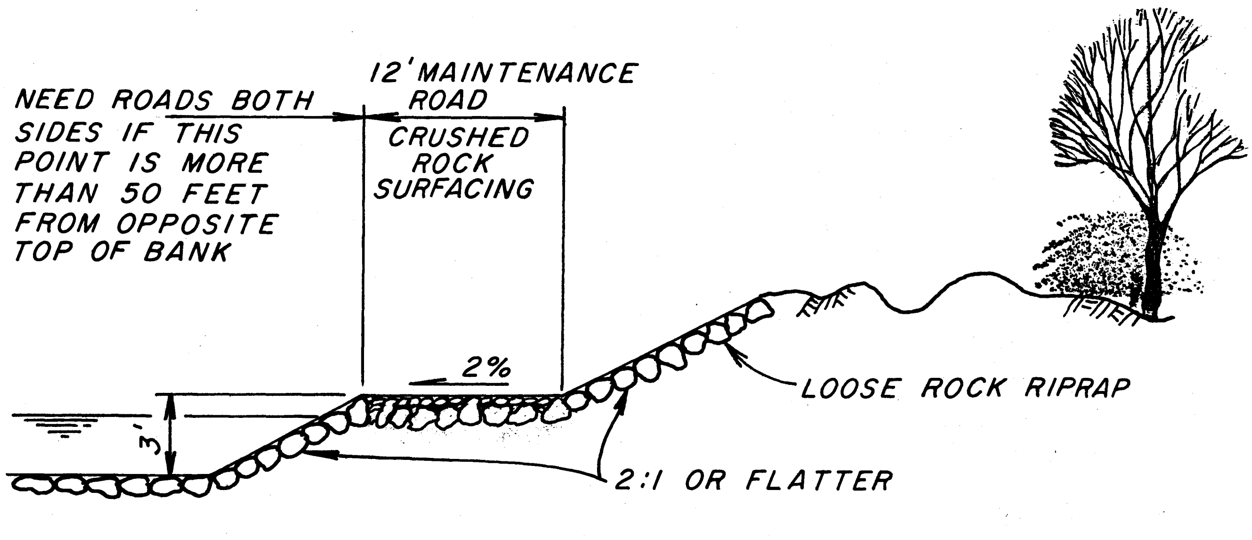


FLAT-BANKED CHANNEL

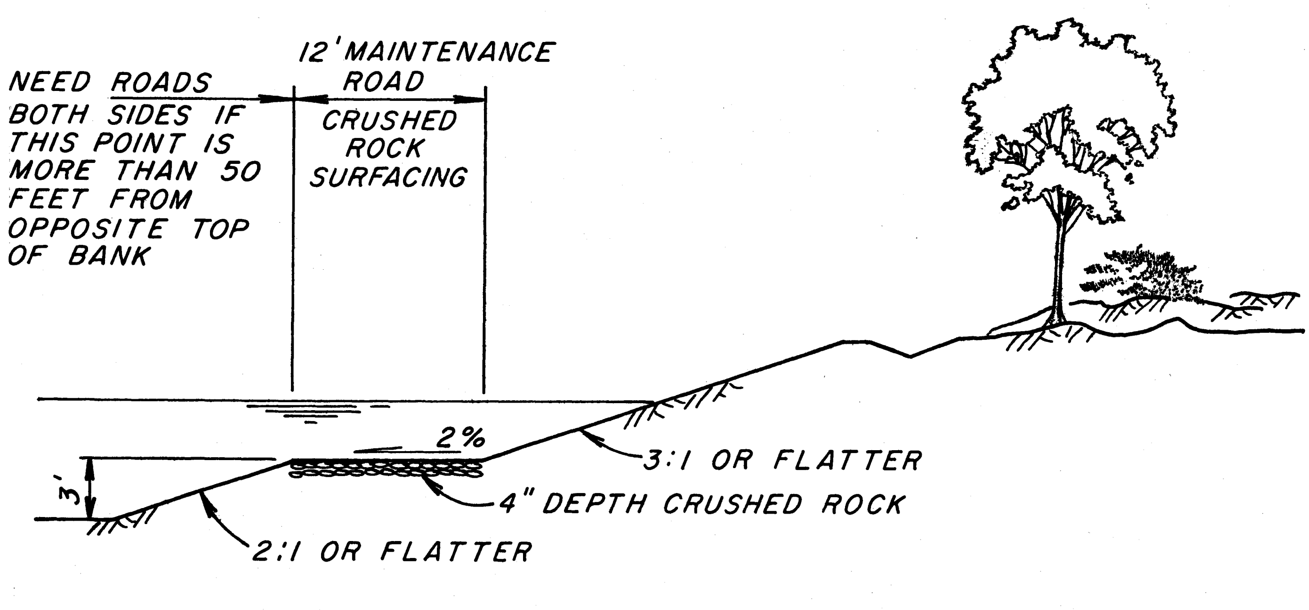


MINIMUM CHANNEL

SIDE SLOPE, MAINTENANCE ROAD & CHANNEL BOTTOM ALTERNATES

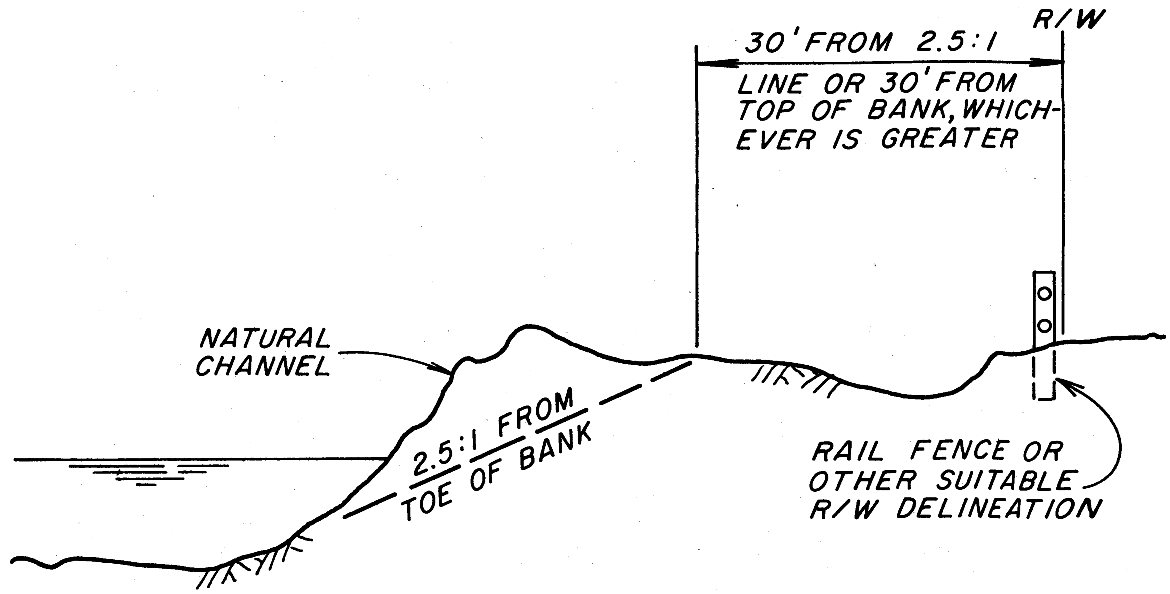


ROCK RIPRAP CHANNEL

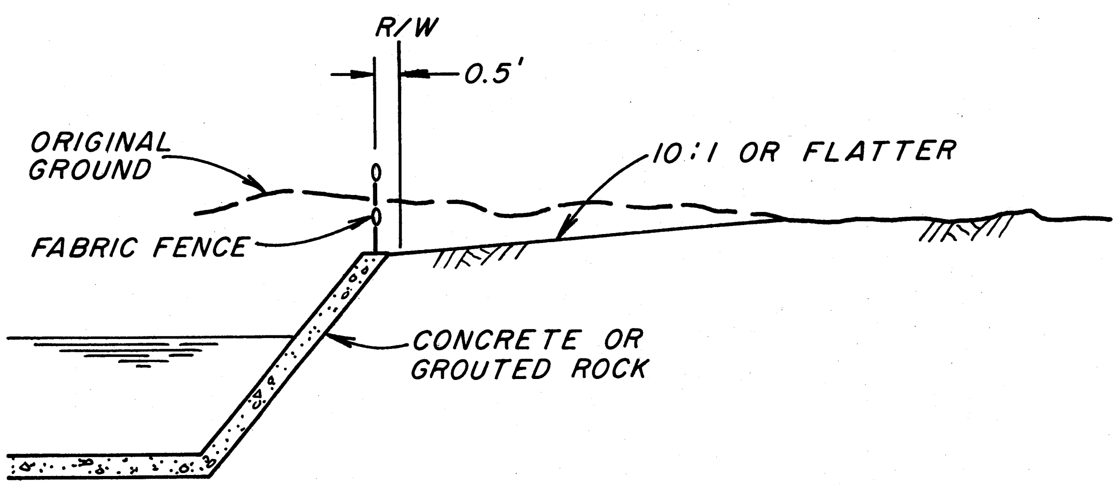


EARTH CHANNEL

TOP OF BANK, R/W & FENCING ALTERNATES

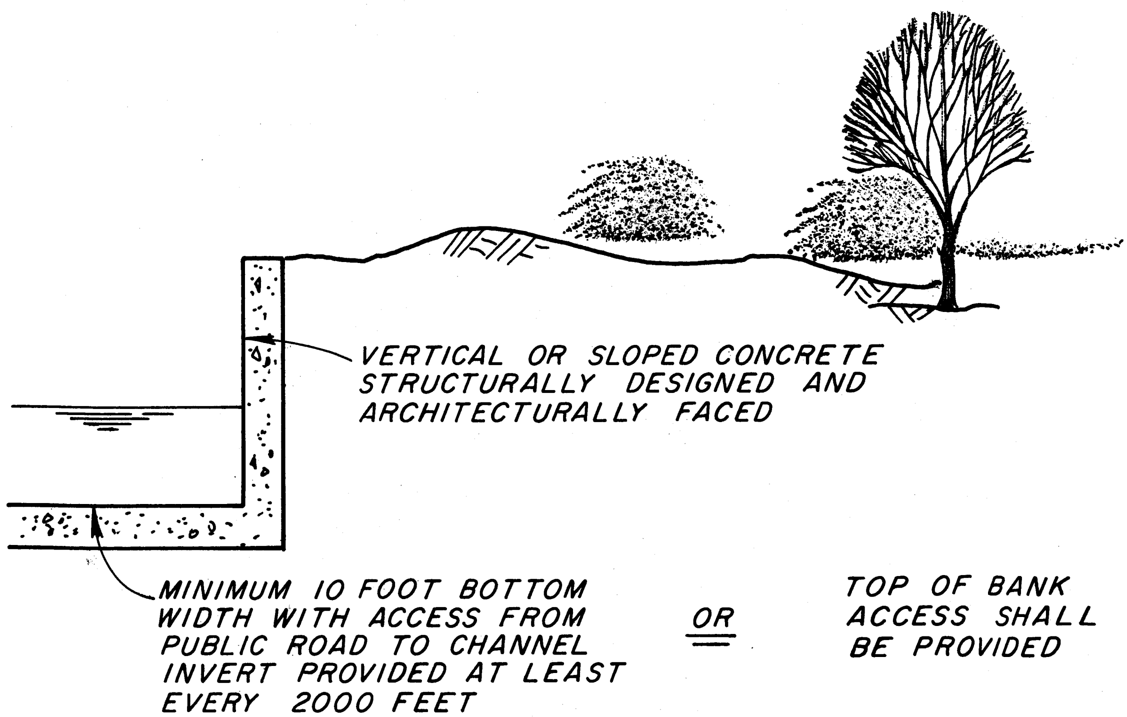


NATURAL CHANNEL

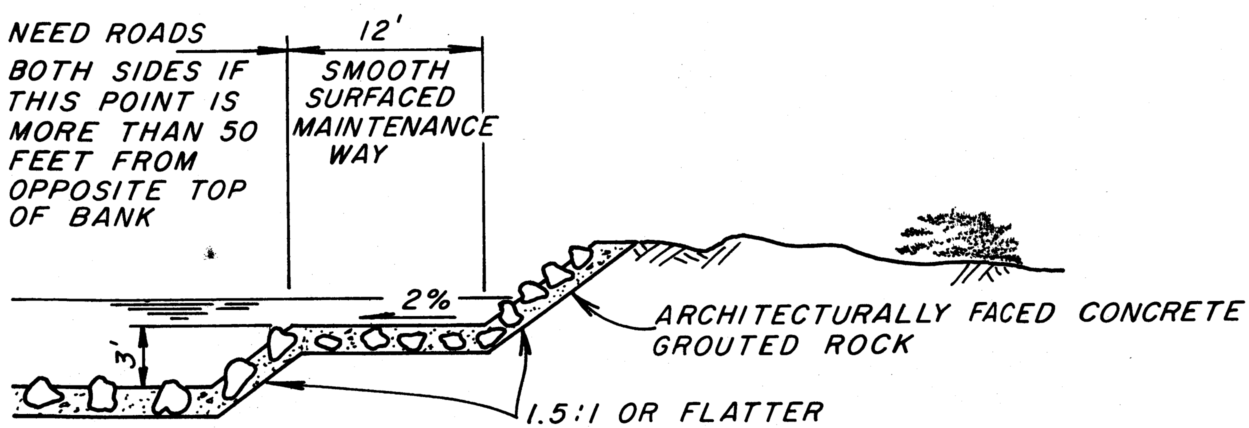


CONCRETE-LINED CHANNEL

SIDE SLOPE, MAINTENANCE ROAD & CHANNEL BOTTOM ALTERNATES



REINFORCED CONCRETE CHANNEL



GROUTED ROCK CHANNEL

PARTIAL PLANT LIST FOR FLOOD CONTROL CHANNELS AND NATURAL WATERWAYS

	Botanical Name	Common Name
Trees		
1.	Acer Macrophyllum	Big Leaf Maple
2.	Acer negundo californicum	California Box Elder
3.	Aesculus californica	California Buckeye
4.	Ainus rhombifolia	California Alder
5.	Cercis occidentalis	California Redbud
6.	Jugians nigra	Black Walnut
7.	Lithocarpus densiflora	Tanbark Oak
8.	Platanus occidentalis	American Sycamore
9.	Quercus agrifolia	California Live Oak
10.	Quercus kelloggii	Black Oak
11.	Rhamnus californica	Coffeeberry
12.	Sequoia sempervirons	Coast Redwood
13.	Umbellularia californica	California Bay
Shrubs and Groundcover		
14.	Arctostaphylos species	Manzanita
15.	Atriplex lentiformis	Salt Bush
16.	Baccharis pilularis	Coyote Bush
17.	Ceanothus species	Wild Lilac
18.	Cercocarpus betuloides	Western Mountain Mahogany
19.	Myrica californica	Wax Myrtle
20.	Photinia arbutifolia	Toyon
21.	Rhus ovata	Sugar Bush
22.	Ribes viburnifolium	Evergreen Current
23.	Sambucus callicarpa	Coast Red Elderberry
24.	---	Native Grasses & Forbes

COMPUTATION FORM FOR UNDERGROUND PIPE DRAINAGE SYSTEMS

CATEGORY	PIPE DATA			FLOW DATA					HEAD LOSSES					ELEVATIONS			
ITEM	LENGTH	DIAMETER	AREA	MANNINGS COEFF.	FLOW	VELOCITY	VELOCITY HEAD	FRICTION SLOPE	FRICTION LOSS	CONTRAC-TION LOSS	ENLARGE-MENT LOSS	BENDS & OTHER LOSSES	SUMMA-TION OF LOSSES	ENERGY GRADE	HYDRAULIC GRADE	INLET GRADE	INVERT GRADE
SYMBOL	L	D	A	n	Q	V	V^2/sq	$S_f = 4.66 \frac{n^2 Q^2}{d^{5.33}}$	$H_f = S_f L$	H_C	H_E	H_B	ΣH	E.G.L.	H.G.L.	F.G.	INV.
UNIT / ELEMENT	Ft	Ft	Ft^2		$Ft^3/sec.$	$Ft/sec.$	Ft	Ft/Ft	Ft	Ft	Ft	Ft	Ft	ELEV. IN FT.	ELEV. IN FT.	ELEV. IN FT.	ELEV. IN FT.

CALC. BY________ DATE ________ PROJECT ____________________________ SHEET NO._____OF______

CHKD. BY_______ DATE ________ ____________________________ JOB NO. ____________

Sht ____ of ____

PROJECT ____________
FREQUENCY ____________
ISOHYETAL ZONE ________

Hydraulic Calculation Sheet

CALCULATED BY ________
CHECKED BY ________
DATE ____________

STATION	ELEV. INV.	D	ELEV. W.S.	SECT-ION	A	W.P.	$R^{2/3}$	Q	$\frac{V^2}{2g}$	E.G.	$S_f \times 10^{-2}$	Av. $S_f \times 10^{-2}$	L	h_f	h_b	h_j	h_t	E.G.	BANK M.EL.

DIRECT STEP — FLOW PROFILE

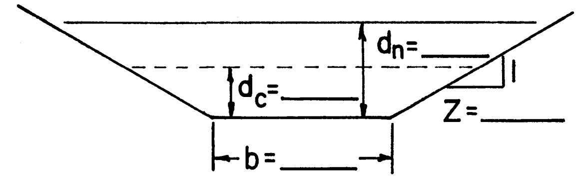
Sheet____of____

PROJECT____________________ Q = ________

LOCATION____________________ S_o = ________

FILE NO.__________ COMPUTED BY________ DATE________ n = ________

REMARKS____________________ α = ________



$$S_f = 29.1(n)^2 \frac{\frac{V^2}{2g}}{R^{4/3}} = \_\_\_\_\_\_ \frac{\frac{V^2}{2g}}{R^{4/3}}$$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	
d	A	V	$\frac{V^2}{2g}$	$\alpha\frac{V^2}{2g}$	E (1) + (5)	ΔE	R	$R^{4/3}$	S_f	Average S_f	$S_o - S_f$	ΔL (7)÷(12)	Station	

STANDARD STEP—FLOW PROFILE

Sheet ____ of ____

PROJECT ________________________ Q __________ n __________

LOCATION ________________________ S_o __________ α __________

FILE NO. ________ COMPUTED BY ________ DATE ________ d_n __________ d_c __________

REMARKS ________________________

$$S_f = 29.1(n)^2 \frac{\frac{V^2}{2g}}{R^{4/3}} = \_\_\_\_\_\_ \frac{\frac{V^2}{2g}}{R^{4/3}}$$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	
Station	d	W.S. Elev.	A	V	$\frac{V^2}{2g}$	$\alpha \frac{V^2}{2g}$	Assumed E.L. (3) + (7)	R	$R^{4/3}$	S_f	Average S_f	ΔL	h_f (12)x(13)	Eddy Loss	Actual E.L.	

RATIONAL METHOD DRAINAGE STUDY

By:__________ Date________ Subject____________________ Sheet No._____ of_____

Chkd. By__________ Date________ Storm Freq._____ % _____ yr. Job. No.__________

Point of Conc.	Area	EL / Distance	Slope	v	Time of Conc. (in minutes)		i	K	C	ΔA / A Total	$K \Delta A C$	$\Sigma K \Delta AC$	Q	Design	Remarks
					Travel Time	Total Time									

MOMENTUM LOSSES AT OBSTRUCTIONS

Project ______________________________ $Q=$ __________ $\frac{Q^2}{g}=$ __________

Location ______________________________ I Upstream Channel $b=$ ______ $z=$ ______

File No. __________ Computed By __________ Date __________ III Downstream Channel $b=$ ______ $z=$ ______

Remarks ______________________________ II Obstruction ______________________________

A_o = Area Of Obstruction

General Equation: $$\underbrace{M_1 - M_0 + \frac{Q^2}{g}\frac{(A_1-A_0)}{A_1^2}}_{\text{I}} = \underbrace{M_1 - M_0 + \frac{Q^2}{g}\frac{1}{A_1-A_0}}_{\text{II}} = \underbrace{M_3 - M_0 + \frac{Q^2}{g A_3}}_{\text{III}}$$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
d	A_1	$\bar{Y}_1$	M_1	A_3	$\bar{Y}_3$	M_3	A_0	$\bar{Y}_0$	M_0	$\frac{Q^2}{g}\left(\frac{A_1-A_0}{A_1^2}\right)$	$\frac{Q^2}{g}\left(\frac{1}{A_1-A_0}\right)$	$\frac{Q^2}{g}\left(\frac{1}{A_3}\right)$	I (4)-(10)+(11)	II (4)-(10)+(12)	III (7)-(10)+(13)

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Sheet ____ of ____

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